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An account of the minerals found in the Virtuous Lady Mine, near Tavistock.

(*With Plates I–III.*)

By Arthur Russell.

[Read November 12, 1912.]

VIRTUOUS Lady Mine is situated in the parish of Buckland Monachorum on the right bank of the river Tavy close to its junction with the river Walkham, at a distance of three miles south of Tavistock in Devonshire. The mine has long been famous for the charm of its situation, and in addition possesses for the mineralogist an especial interest owing to the peculiar beauty and unusual character of the mineral specimens it has yielded. The early history of the mine is lost in obscurity, as also is the origin of its curious name, which, however, local tradition ascribes to Queen Elizabeth.

The earliest reference to the mine is one by the Lysons,[1] who state on the authority of Mr. John Taylor that it was working prior to 1807, but was abandoned in that year. It was working again in 1825, and abandoned in 1856, the last working being from 1870 to 1875, since when

[1] Rev. D. and S. Lysons, 'Magna Britannia,' vol. vi, Devonshire, 1822, p. cclxxxv.

no mining has been done. William Jory Henwood,[1] writing in 1843, gives the following facts concerning the mine. 'A sort of metalliferous bed, containing copper pyrites, with carbonate of iron, chlorite, and quartz occurs at Virtuous Lady: it bears about 20° S. of W., dips N. 10–15°, and varies from a few inches to 20 or 30 feet in thickness. The ores are distributed in the most irregular manner; sometimes large masses occur in the quartz, and soon split into strings; frequently these again expand, though not a few of them dwindle entirely away. Numerous ramifications of quartz extend into the slate, which near the bed contain many large and well-defined cubic crystals of iron pyrites, often imbedded in carbonate of iron. The workings on the south open to the surface, and their dimensions underground are about 100 fathoms long by 80 wide, the greatest depth is 15 fathoms. The cleavage of the slate in which it occurs dips S.'

There is a quaint and interesting description of the various minerals found in this mine and in the neighbourhood of Tavistock in a letter dated 1835 from a Mr. Edmund Pearse, surgeon of Tavistock, to Mrs. Anna Eliza Bray.[2] This Mr. Edmund Pearse (*b.* 1788, *d.* 1856) was an enthusiastic collector of local minerals, and his fine collection, which was particularly rich in Virtuous Lady specimens, has recently (1911) come into the possession of the writer, and forms the principal material for the present paper. The photographs reproduced in the accompanying plates represent with two exceptions specimens from this collection.

The following species have been found in this mine: chalcopyrite, pyrite, marcasite, mispickel, fluor, quartz, cassiterite, anatase, brookite, chalybite, chlorite, sphene, scorodite.

Chalcopyrite.

Chalcopyrite was the principal ore in this mine, the vuggy nature of the deposit permitting the formation of many fine crystals. Individual specimens are difficult to describe, but mention may be made of the following: Large groups of peacock-blue or bronze-coloured sphenoids

[1] W. J. Henwood, 'The Metalliferous Deposits of Cornwall and Devon,' Trans. Roy. Geol. Soc. Cornwall, 1843, vol. v, p. 140.

[2] Mrs. A. E. Bray (formerly Stothard), 'A description of the part of Devonshire bordering on the Tamar and the Tavy; its Natural History, &c., in a series of letters to Robert Southey, Esq.' 3 vols. London, 1836 (Mr. Pearse's letter in vol. iii, pp. 253–260). Another edition with a slightly different title, but with the same pagination, appeared in 1838; and a revised edition in 2 vols. appeared in 1879 under the title 'The Borders of the Tamar and the Tavy; their Natural History', &c.

in parallel position, their surfaces sprinkled over with brown, lenticular crystals of chalybite and small crystals of pyrite. Beautiful, highly iridescent, curved sphenoids with drusy surfaces, associated with opaque white quartz crystals, occupying the interior of large hollow cubes of chalybite (pseudomorphs after fluor). Groups of nearly black sphenoids on snow-white quartz crystals, with balls of chalybite. Chalcopyrite was also found here occasionally in a blister-like form, the surface being rough and of a dull brassy or nearly black colour.

Many of the crystals are somewhat obscure and complex twins, evidence of their nature being afforded by the different sets of striae. The twin-plane appears usually to be *e* (101), in which case similar faces are opposed across the twin-junction, the twin being symmetrical to the composition-plane. At the writer's request Dr. G. F. Herbert Smith

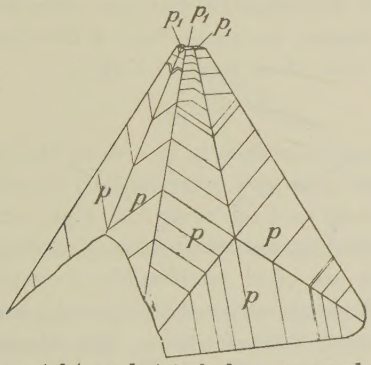


Fig. 1.—Twinned crystal (pseudo-tetrahedron composed of six individuals) of Chalcopyrite from Virtuous Lady Mine, Tavistock.

very kindly undertook the examination, and made a drawing (text-fig. 1), of a very complex crystal of this nature from the Pearse collection. The following is his description :—

'The crystal resembles a regular tetrahedron, measuring about 2 cm. from a corner to the opposite face, and is an unusually fine example of twinning[1] about the face *e* (101). It springs clear of the specimen except for one edge (on the left-hand side at the foot in text-fig. 1) which merges into a mass of smaller crystals of the same mineral intergrown with a few milky, prismatic crystals of quartz.

'Each apparent face of the tetrahedron consists of three distinct

[1] For a full discussion of this mode of twinning see L. Fletcher, Phil. Mag., 1882, vol. xiv, pp. 276–291, and Proc. Cryst. Soc., 1882, part ii, pp. 114–131.

triangular sectors, each of which is a face of the form p (111), and the crystal is composed of six individuals twinned with respect to one another. The adjacent sectors, one on each of any pair of contiguous faces, belong to the same individual, and the face c (001), were it present, would lie on the edge of the pseudo-tetrahedron. The faces p (111) are rough and somewhat distorted, and the reflections that they afford of the goniometer-slit are in certain instances indistinct. They are striated at right angles to the corresponding tetrahedron edge, and a subsidiary set of striations runs parallel to their intersections with the faces of the complementary form p_1 ($\bar{1}11$). The sectors on the faces shown in the figure meet in salient angles, the measured values of which were 1° 14′, 1° 17′, 1° 19′, 1° 22′, 1° 59′; the value deduced from the fundamental angle, (001):(101) = 44° 34½′, is 1° 23½′. On the face at the back the only two sectors which gave reflections are parallel; the under face has only one sector exposed. A few small bright faces of the complementary form p_1 ($\bar{1}11$) were also present, and on the back of the crystal as shown were observed two small faces of the form z (201).'

Pyrite.

Pyrite was extremely abundant in this mine, the chloritic slate containing large isolated and very symmetrically developed cubes, which occasionally measure up to 4 cm. along the edge, and are amongst the best examples of this mineral which have been found in the British Isles. These cubes are often considerably elongated; some are dull and deeply striated, while others have smooth, bright faces. Large interpenetrating groups were common. The mineral was also found with the following associates: Very brilliant cubes showing small faces of o {111} and s {321}, with chalybite and crystals of chalcopyrite on transparent slender prisms of quartz. Brilliant cubes with the forms a {100}, o {111}, e {210}, s {321}, embedded in groups of steely-blue sphenoids of chalcopyrite. Small octahedra, o {111}, a {100}, studded over lenticular crystals of chalybite, also investing 'slipper' pseudomorphs, and thickly encrusting large stout prisms of quartz coated with chalybite. Brilliant pentagonal dodecahedra e {210} up to 1 cm. in diameter, embedded in a greenish-grey chlorite-schist, were especially abundant in one part of the mine, and may still be found on the old burrows.

Marcasite.

Marcasite was found here as curious specimens consisting of radial groups of long fan-like aggregates, projecting from a nucleus of cubes of

pyrite. These aggregates attain a length of 4 cm., and are built up of light yellowish-white, deeply striated, flat crystals, *c* {001}, *m* {110}, *l* {011}, elongated in the direction of the *c*-axis, many of them showing the characteristic twinning on *m* (Plate I, fig. 5). The specimens are somewhat liable to decomposition, more especially at the points where the marcasite is in contact with the pyrite. Greg and Lettsom[1] figure a crystal of marcasite from this locality showing the forms[2] *c* {001}, *m* {110}, *r* {014}, *l* {011}.

Mispickel.

Mispickel occurred here in very fine specimens, the most usual type consisting of groups of large interpenetrating crystals up to 3 cm. in length; they are tarnished bronze-yellow, and exhibit combinations of *m* {110} and *t* {013} with small *e* {101} (text-fig. 2). The faces of *m*

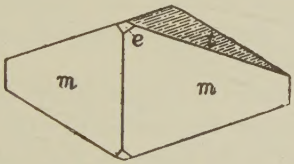


Fig. 2.—Crystal of Mispickel from Virtuous Lady Mine, Tavistock.

exhibit a platy structure, and those of *t* are furrowed by oscillatory combination. These crystals are often associated with chalcopyrite, and large, snow-white prisms of quartz studded over with balls of chalybite (Plate I, fig. 3). Also in silver-white crystals, occupying, with quartz crystals, large pseudomorphous cubic cavities in chalybite. More rarely the mispickel forms groups of large, prismatic, bronze-yellow crystals, *m* {110}, *t* {013}, measuring up to 2½ cm. along the vertical axis, in the direction of which they are elongated (Plate I, fig. 2). Both types of crystals usually exhibit a polysynthetic growth, and show re-entrant angles on the edges between the adjacent *m* faces due to the presence of small faces of *e* {101}.

[1] R. P. Greg and W. G. Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, pp. 281–282.

[2] The letters and indices of the crystal-forms adopted throughout this paper are as in Dana's 'System of Mineralogy,' 6th edit., 1892.

Fluor.

Fluor, although now rather scarce, appears from the hollow 'box' pseudomorphs to have been abundant at one period of the lode's history. The writer has observed small, yellowish cubes associated with chalybite on the old burrows.

Quartz.

Very beautiful specimens of quartz have been found in this mine. They consist of large, milky-white, opaque, prismatic crystals up to 15 cm. in length, studded over with balls and lenticular crystals of chalybite, and were sometimes associated with fine crystals of mispickel (Plate I, fig. 3). In most cases the milky colour is due to one or more thin, white, drusy outer layers, the interior of the crystals being translucent. Quartz also occurred here in very slender tapering crystals studded over with balls of chalybite, and beautiful iridescent sphenoids of chalcopyrite; also in stout prismatic crystals, more or less completely coated with small crystals of pyrite.

The curious variety known as *Capped Quartz* appears, so far as Great Britain is concerned, to have been peculiar to this mine. It is referred to, and briefly described by the Lysons in their list of minerals occurring in Devonshire.[1] These crystals are more or less opaque, have a pearly lustre due to included air spaces, and are externally coated with a yellow film of limonite. They occasionally attain a length of 14 cm. The exterior of the prism portion is built up of many smaller crystals arranged in more or less parallel position, while the pyramid is regular and smooth. A light blow at the junction of the prism and pyramid causes an outer pyramidal cap to come off entire, leaving an inner pyramid perfect, and of a milk-white colour. This easy separation is apparently due to there being a thin film of some foreign substance between the successive parallel layers of the crystal. The writer has two very fine specimens of this variety of quartz from the Pearse collection, the smaller of which is shown in Plate I, fig. 1. The larger, a group showing over thirty crystals, two of which have had their caps detached, is referred to by Mr. Pearse in his letter to Mrs. Bray.[2]

[1] Rev. D. and S. Lysons, 'Magna Britannia,' vol. vi, Devonshire, 1822, p. cclxix.

[2] Mrs. A. E. Bray, loc. cit., 1836, vol. iii, p. 258.

Cassiterite.

Cassiterite appears to have been a rare mineral in this mine. The writer possesses a specimen from the Pearse collection which shows minute, black, acute prismatic crystals ('sparable tin'), $m\{110\}, z\{321\}$, upon black sphenoids of chalcopyrite, milky-white quartz crystals, and balls of chalybite on a light greyish-green chloritic slate. The cassiterite was evidently the last mineral formed.

Anatase.

The earliest reference to the occurrence of anatase in this mine appears to be one in Mr. Pearse's letter to Mrs. Bray (1835) in which he speaks of 'the brilliant well-defined crystals of titanium.'[1] Of a large number of crystals which have been examined and measured by the writer, the following remarks apply principally to a fine series of specimens contained in the Pearse collection, and also to crystals in the Brooke collection at Cambridge University which Dr. Hutchinson kindly placed at my disposal. The anatase forms very brilliant, black and perfectly opaque, tabular or pyramidal crystals, the two habits graduating from one to the other. One crystal found on the old burrows shows a distinct indigo-blue colour by transmitted light. The commonest form is a tabular combination of $c\{001\}$ with $p\{111\}$ (text-fig. 3). These crystals measure up to 3 mm. along the edge, and are often somewhat elongated in the direction of a horizontal axis, while occasionally owing to a very unequal development of the faces they are curiously distorted as in text-fig. 4. More rarely the crystals assume a pyramidal habit, the following combinations having been noted:—

$c\{001\}, m\{110\}, z\{113\}, p\{111\}$ (text-fig. 5).
$c\{001\}, m\{110\}, \chi\{337\}, p\{111\}$.
$c\{001\}, m\{110\}, x\{103\}, \lambda\{449\}, p\{111\}$ (text-fig. 6).
$c\{001\}, m\{110\}, x\{103\}, r\{115\}, \chi\{337\}, p\{111\}$.

The pyramid faces with the exception of p and z are usually more or less deeply striated horizontally, and yield banded images. The form[2] $\{449\}$ gives, with (001), values ranging between 47° 20′ and 48° 10′, thus indicating some oscillation with $\{337\}$.

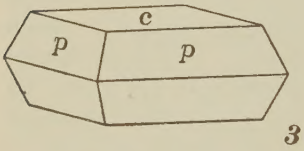
Greg and Lettsom mention and figure tabular crystals $c\{001\}$, $v\{117\}$, $p\{111\}$ from Virtuous Lady Mine. The form $v\{117\}$ has not,

[1] Mrs. A. E. Bray, loc. cit., vol. iii, p. 257.

[2] This form $\{449\}$ has previously been observed on anatase, from Nil-Saint-Vincent, Brabant, by W. Prinz, Bull. Acad. Belgique, 1907, p. 706.

however, been met with by the writer. The same authors also refer to a crystal from this mine in the Brooke collection, upon which the following forms had been identified: $c\{001\}$, $m\{110\}$, $x\{103\}$, $l\{1.1.10\}$, $y\{?\}$, $v\{117\}$, $r\{115\}$, $\psi\{225\}$, $p\{111\}$.[1]

The anatase crystals occur either singly or in groups of two or more individuals on spherical aggregates of brownish, lenticular crystals of chalybite with small, opaque white quartz crystals, and a soft, greyish-green, highly chloritic slate, the interstices of which are filled with a soft, white, talcose mineral. Also in cavities, or embedded in compact,



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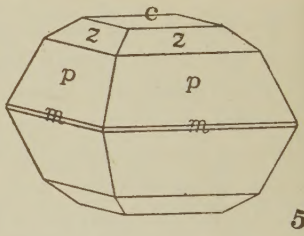

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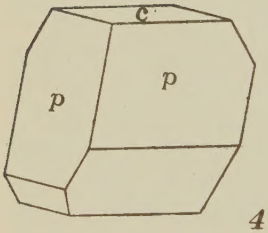

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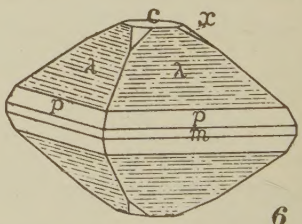

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Figs. 3-6.—Crystals of Anatase from Virtuous Lady Mine, Tavistock.

green, scaly chlorite. More rarely with black, twinned sphenoids of chalcopyrite; or perched upon small, opaque white quartz crystals; or embedded in massive quartz; and very rarely as small, pyramidal crystals embedded in large cubes of pyrite. Good crystals may still be obtained by carefully searching the burrows and breaking open masses of the chlorite vein-stuff.

Brookite.

Greg and Lettsom state that brookite occurred in Virtuous Lady Mine as microscopic crystals embedded in chalybite, associated with anatase and chlorite.[2] The only specimen of brookite from this locality known

[1] R. P. Greg and W. G. Lettsom, loc. cit., pp. 363–364.
[2] Ibid., p. 366.

o the writer is one in the Pearse collection. It shows a single, minute, rown, prismatic crystal flattened parallel to *a* {100} and about mm. in length. There are at least three other forms present, repre- nted by bright, well-developed faces, probably *m* {110}, *t* {021}, {122}; these, however, could not be verified without removing the rystal, which projects from a cavity in a soft, greenish chlorite, upon hich are balls of chalybite and large crystals of anatase.

Chalybite.

The mine has yielded many fine specimens of chalybite. They are lmost invariably of the same type, consisting of light or dark hair- rown, flat disc-like or lenticular crystals, *c* {0001}, *r* {10$\bar{1}$1}, *e* {01$\bar{1}$2}, ften studded over with small, brilliant octahedra of pyrite, and clustered bout groups of snow-white quartz crystals (Plate I, fig. 4); or thickly nvesting large iridescent sphenoids of chalcopyrite. The basal plane *c*

Fig. 7.—Crystal of Chalybite from Virtuous Lady Mine, Tavistock.

as a mottled appearance owing to the presence of cleavage cracks arallel to *r*, and is usually triangular in outline from a predominance f the rhombohedron *e*, while its surface is covered with small, triangular arkings. The faces of *r* and *e* are rough, those of *e* being striated arallel to their intersections with *c* (text-fig. 7). On other specimens, ne chalybite crystals are clustered together in the form of balls, which re perched upon white, prismatic crystals of quartz (Plate I, fig. 3), iese latter specimens being especially characteristic of the mine. More arely the chalybite assumes a simple rhombohedral habit *r* {10$\bar{1}$1}; a rystal of this description from the Pearse collection measures 4 cm. ong the edge, and is built up of parallel individuals; it is associated ith chalcopyrite and pyrite.

Amongst the most remarkable productions of this mine are the well- nown pseudomorphs (epimorphs) of chalybite after fluor and barytes hich were found in considerable abundance during the years 1832 and 833.

The *pseudomorphs of chalybite after fluor*, now somewhat scarce and ly to be seen in old collections, consist of hollow cubic shells of

dark to light-brown chalybite in translucent lenticular crystals, usually aggregated in more or less globular forms. They were known to the miners as 'boxes,' and vary in size from 2 to 10 cm. along their edges. Some are perfect on all sides and exceedingly symmetrical in outline, others are open at the top or sides, and have in their interior groups of large and most beautifully iridescent crystals of chalcopyrite, interspersed with white, prismatic crystals of quartz (Plate II, figs. 6–9). It is impossible to describe adequately the beauty of these specimens. There is a very fine and large specimen of this description in the British Museum (Natural History); while the writer possesses a very fine series which formed part of Mr. Edmund Pearse's collection. Amongst the most noteworthy of these latter specimens are: Large groups of thin, hollow, interpenetrating cubes, the exterior coated with a dirty-white, sandy deposit. A group of very perfect, light brown cubes, the surfaces of which are prettily sprinkled with minute crystals of pyrite, and having in their hollow interior a delicate, snow-white, drusy mass of stalactitic quartz, upon which are two small crystals of chalcopyrite. A large group of cubes, sprinkled over with pyrite, with a large and very perfect 'slipper' pseudomorph projecting from them (Plate II, fig. 10). Large and very perfect, light brown cubes, prettily poised on a mass of chalybite-covered crystals of chalcopyrite and quartz.

As to the origin of these pseudomorphs there can be little or no doubt but that the original mineral was fluor.[1] William Jory Henwood, in fact, states that he was shown a specimen by a Captain Martyn, in which the cubes still retained that mineral.[2] Greg and Lettsom, although they refer to this or a similar specimen containing fluor, curiously enough suggest that pyrite was in most cases the original mineral.[3] Mr. Edmund Pearse was of the same opinion, and in support of his view states that a multitude of cubic crystals of pyrite were found about six fathoms distant, but separated by solid rock.[4] It is interesting to note that corroded cubes of fluor completely invested by chalybite have been found by the writer on the burrows of Devon and Courtenay Mine, Whitchurch, a mine situated about one mile north of Virtuous

[1] J. R. Blum, 'Die Pseudomorphosen des Mineralreichs,' 1863, Nachtrag 3, p. 250.

[2] W. J. Henwood, 'The Metalliferous Deposits of Cornwall and Devon,' Trans. Roy. Geol. Soc. Cornwall, 1843, vol. v, p. 140.

[3] R. P. Greg and W. G. Lettsom, 'Manual of the Mineralogy of Great Britain and Ireland,' 1858, pp. 260–261. It is stated here in error that Virtuous Lady Mine and Bedford United Mine were identical.

[4] Mrs. A. E. Bray, loc. cit., 1836, vol. iii, p. 259.

Lady. The writer also possesses a specimen recently found by his friend, Mr. Jehu Richards, on the burrows of Holmbush Mine, Stokeclimsland, Cornwall, showing a mass of cubic shells of chalybite, one of which contains a loosely fitting, much corroded blue cube of fluor 13 mm. along its edge. Similar, though less perfect, pseudomorphs of chalybite still retaining cubes of fluor also occur occasionally in the Boltsburn Mine, Weardale, Co. Durham. A specimen of this description in the writer's collection measures no less than 14 cm. along the edge.

The succession of events in the formation of the Virtuous Lady specimens has been pointed out by Sir Henry De la Beche,[1] and were as follows: firstly, the production of chalcopyrite, often crystallized in contact with the containing rock; secondly, the crystallization of some mineral in cubical forms, perhaps fluor; thirdly, the incrustation of these crystals by chalybite; fourthly, the dissolving of the fluor by some solvent which did not act on the chalybite; and fifthly, the crystallization of quartz and chalcopyrite in the cubical cavities thus formed. As Mr. F. W. Rudler[2] has pointed out, it must be admitted that it is difficult to understand the nature of the solvent which could remove fluor whilst leaving the chalybite unaltered. Carbonate of iron is formed by the action of alkaline carbonates on ferrous sulphate such as would result from the decomposition of pyrite, while alkaline carbonates decompose fluor with the formation of calcium carbonate.

The *pseudomorphs of chalybite after barytes* (Plate III, figs. 11–16) were found in considerable abundance at the same time, and in close proximity to the 'boxes,' and examples are to be found in most old collections. Inferior specimens in which the chalybite is partially converted by weathering into limonite may still be found on a small burrow on the central part of the mine. They consist of long, flat, tapering crystals, resembling in shape a gothic arch, and are composed of dark or light-brown chalybite in lenticular crystals, usually aggregated in more or less globular forms. They were known to the miners as 'Lady's Slippers,' and vary in length from 5 to 31 cm. Usually the chalybite has invested three sides only of the original barytes crystal, leaving a cast consisting of one flat face bounded by two narrow planes, the edges being as it were turned over by having numerous balls of chalybite upon them. The back or outside

[1] H. T. De la Beche, 'Report on the Geology of Cornwall, Devon, and West Somerset,' 1839, p. 391.

[2] F. W. Rudler, 'A handbook to a collection of the minerals of the British Islands, mostly selected from the Ludlam collection, in the Museum of Practical Geology,' 1905, pp. 69, 70.

of these crystals often consists of a thick coating of minutely crystallized pyrite, while the inside has its surface prettily sprinkled with small iridescent cubo-octahedra of the same mineral. In some cases the inner surface has upon it very regular, deep cubic impressions, and curious blotches of bright chalcopyrite, these being the under surface of crystals of chalcopyrite which must once have been attached to the parent barytes crystal. More rarely the chalybite has invested all four sides of the barytes crystals, thus forming very remarkable hollow pseudomorphs (Plate III, fig. 16), the walls of which are often not more than 1 mm. in thickness. Most of the specimens of this description show several superimposed individuals lying flat one upon the other, and graduated in size. In a good many cases one side or half of the pseudomorph has been more or less converted into yellowish-brown, gritty limonite. Mr. Edmund Pearse's collection contained a very fine series of these 'slipper' pseudomorphs, amongst which may be mentioned: very large groups intergrown and crossing one another in a curious manner; a large group of 'box' pseudomorphs having 'slipper' pseudomorphs projecting from them (Plate II, fig. 10); a group of three parallel 'slippers,' their exterior being entirely encrusted with brilliant brassy-yellow pyrite crystals. Very rarely the 'slipper' pseudomorphs are doubly terminated. One in the Pearse collection measures 13 cm. in length, and is especially mentioned as a rarity in the letter to Mrs. Bray.[1] It is hollow, of a light brown colour, and sprinkled over with small octahedrons of pyrite (Plate III, fig. 15).

Owing to the curvature and roughness of the faces it has been found impossible to determine accurately the forms which have given rise to this particular habit. Some of the larger pseudomorphs consisting of three sides only, have, however, on the inner side counter-sunk impressions of smaller crystals of similar habit and of sharper outline, and from these it was possible to determine roughly the acute angle, which was found to be about 56° 36′, thus suggesting the form $g\{103\}$ ($gg' = 56° 29'$) of barytes in conjunction with $b\{010\}$ and $c\{001\}$. As to barytes having been the original mineral there can, I think, be little doubt. Greg and Lettsom suggest selenite (gypsum), but it is obvious that this was not the case, the habit being entirely dissimilar. The specimen referred to above on which 'slipper' pseudomorphs project from a group of 'box' pseudomorphs recalls the association of barytes crystals and large cubes of fluor from the lead lode of Wheal Mary Ann, Menheniot, Cornwall. The habit of the Wheal Mary Ann

[1] Mrs. A. E. Bray, loc. cit., 1836, vol. iii, p. 259.

barytes is, however, quite unlike that of the pseudomorphs from Virtuous Lady, and one cannot in fact recall any crystals of barytes of a similar type and size. The Pearse collection contains an interesting specimen from the Old Beer Mine (South Tamar Consols), Beer Ferris, consisting of a group of pseudomorphs of apparently exactly similar habit to the Virtuous Lady 'slippers'; they average about 3 cm. in length. In this case the barytes crystals have been entirely substituted by galena, upon which is sprinkled a little pyrite, and numerous rhombs of dolomite; the pseudomorphs being implanted on cubic fluor. Pseudomorphs of quartz after barytes of exactly similar habit 4 cm. in length have also been found by the writer on the old burrows of Great Work Mine, Breage, Cornwall. Greg and Lettsom state that chalybite in 'slipper' pseudomorphs occurred also at Beeralston, and Wheal Friendship, Mary Tavy[1]; there is, however, considerable doubt concerning the accuracy of this statement. As to the nature of the solvent which attacked the original barytes, one is confronted with the same difficulty which arises in considering the formation of the 'box' pseudomorphs; it seems, however, pretty evident that the solvent was identical in both cases, and that the action took place at the same period.

Chlorite.

Chlorite (prochlorite) was especially abundant in this mine; it occurred in soft, greyish-green masses, composed of minute scaly aggregates, which in the cavities form crystalline rosettes. It often contains embedded crystals of pyrite and anatase.

Sphene.

Greg and Lettsom state that sphene occurred here in small, yellowish crystals in chlorite.[2] The writer has, however, been unable to confirm this occurrence.

Scorodite.

Specimens of scorodite have been found by the writer on the old burrows. The mineral forms a light-green, mamillary crust on massive, white quartz, and probably results from the alteration of mispickel.

[1] R. P. Greg and W. G. Lettsom, loc. cit., p. 260.

[2] Ibid., p. 368.

EXPLANATION OF PLATES I–III.

(Photographs of mineral specimens from Virtuous Lady Mine, Tavistock, Devonshire, in the writer's collection.)

Fig. 1. Capped quartz, with the cap detached : actual size 13 × 8 cm.

,, 2. Mispickel crystals partially coated with chalybite : actual size 4 × 5 cm.

,, 3. Mispickel crystals and balls of chalybite on quartz : actual size 13½ × 6 cm.

,, 4. Disc-like crystals of chalybite on quartz crystals : actual size 14 × 9 cm.

,, 5. Marcasite in fan-shaped groups, on cubes of pyrite resting upon chalybite : actual size 10 × 8 cm.

,, 6. Pseudomorph of chalybite after fluor : actual size 7 × 8 cm.

,, 7. A group of pseudomorphs of chalybite after fluor with chalybite-covered quartz crystals, upon chalcopyrite : actual size 12 × 11 cm.

,, 8. Pseudomorph of chalybite after fluor : actual size 9 × 9 cm.

,, 9. Pseudomorph of chalybite after fluor, the interior containing beautiful iridescent sphenoids of chalcopyrite and small, opaque white quartz crystals : actual size 7 × 7 cm.

,, 10. A group of pseudomorphs of chalybite after fluor with pseudomorphs of chalybite after barytes projecting from them : actual size 22 × 23 cm.

,, 11. A group of three parallel pseudomorphs of chalybite after barytes, sprinkled over with small, brilliant crystals of pyrite : actual size 9½ × 8 cm.

,, 12. A pseudomorph of chalybite after barytes, the under side being entirely encrusted with pyrite : actual size 15 × 10 cm.

,, 13. Two pseudomorphs of chalybite after barytes, curiously intergrown, and sprinkled with small crystals of pyrite : actual size 9½ × 8 cm.

,, 14. A pseudomorph of chalybite after barytes, doubly terminated and showing an open interior : actual size 13 × 4¾ cm.

,, 15. A similar pseudomorph with a hollow interior, and other smaller pseudomorphs projecting from it : actual size 13½ × 4¾ cm.

,, 16. A large pseudomorph of chalybite after barytes, showing the hollow interior : actual size 26 × 10 cm.

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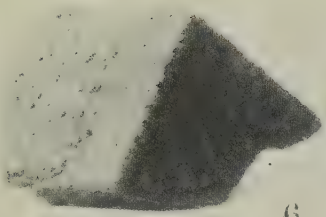

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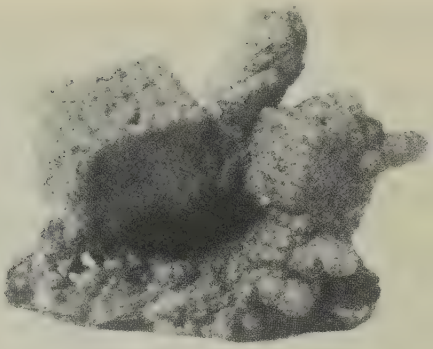

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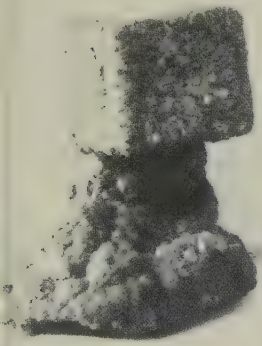

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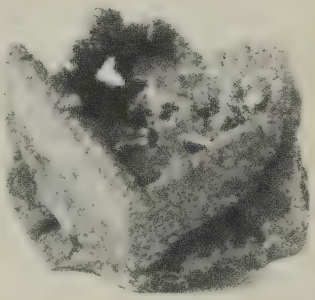

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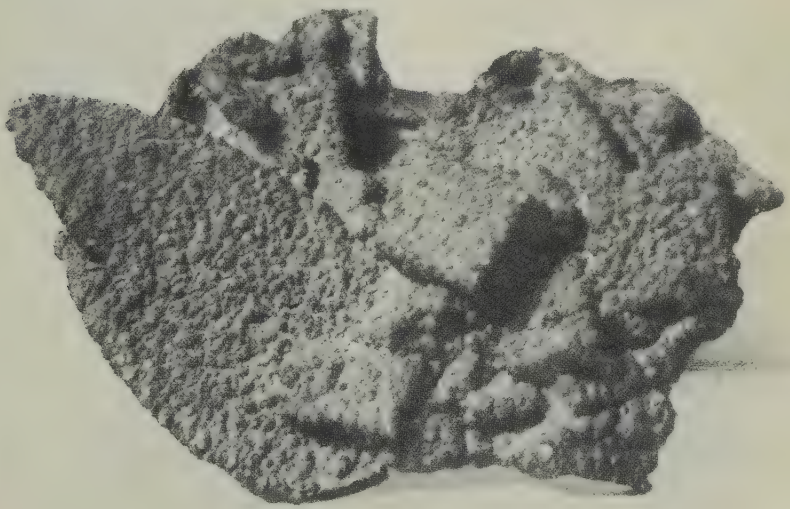

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Notes on the occurrence of Bertrandite at some new localities in Cornwall.

By Arthur Russell.

[Read March 21, 1911.]

IN 1904 Professor Bowman described the occurrence of bertrandite at the Cheesewring Quarry, Linkinhorne, Cornwall;[1] the mineral having been then recently discovered there by Mr. F. H. Butler. The following notes contain an account of the character and mode of occurrence of the same mineral at four additional localities in Cornwall.[2]

Gold-diggings Quarry,[3] St. Cleer, Cornwall.

This quarry is situated about 900 yards west of the Cheesewring Quarry (Sheet XXVIII NW, Six-Inch Ordnance Map), the granite being of an almost precisely similar character at both places. Bertrandite was first found here by myself in 1904. It forms clusters of colourless crystals, which occasionally attain a length of 5 mm., but which are usually much smaller, and is associated with crystals of deep-violet mica, quartz, slightly pinkish crystals of orthoclase of adularia habit, pyrite, and red blende, upon vertical joint-faces of the granite.

The crystals are usually rhombic in outline, and in habit exactly resemble those from the Cheesewring Quarry as described and shown in

[1] H. L. Bowman, 'On the occurrence of Bertrandite at the Cheesewring Quarry, near Liskeard, Cornwall,' Mineralogical Magazine, 1911, vol. xvi, pp. 47–50.

[2] Brief mention of the occurrence of bertrandite at the localities described in this paper has already been made by Mr. J. H. Collins in his 'List of Minerals found in Cornwall and Devon, with notes supplementary to the author's "Handbook",' Journ. Roy. Inst. Cornwall, 1911, vol. xviii, pp. 425–461 (bertrandite on p. 431).

[3] This quarry has recently for trade purposes been given the name 'Silver Pey': it is still, however, locally known by the old name of 'Gold-diggings'. The owner, J. Sweet, Esq., of Liskeard, has been most kind in affording me permission to examine it thoroughly on many occasions.

the first figure in Professor Bowman's paper. The forms present[1] ar
c {001} and m {110} prominent, with a {100}, f {130}, and b {010
small. One specimen was, however, found showing a totally differer
type of crystals. These are tabular parallel to c and rectangular i
outline, the forms being a {100}, b {010}, and c {001}, sometimes wit
very narrow faces of m {110} and f {130}. They are twinned o
ϵ {011}, the b-axes of the two individuals being inclined at an angle
about 60°. A smaller individual usually springs from near the middl
of one side of a thicker and wider individual; and the basal plane on th
side towards the twin-plane is always arched owing to an oscillatio
between the forms c (001), and ϵ (011), the basal plane on the opposit
side being quite flat. In one instance there is a repeated twinning
three distinct individuals of graduated size, the largest measurin
$1\frac{1}{4}$ mm. along the edge (fig. 1). These crystals occur in small cavities o
one side of a mass of granite, the opposite side of which formed the wa
of a large vug lined with yellowish-white Carlsbad-twins of orthoclas
tapering prismatic crystals of smoky quartz, fluor, and a few colourle
crystals of apatite. Bertrandite is of much rarer occurrence here than a
the Cheesewring Quarry.

Kit Hill Great Consols Mine, Stokeclimsland, Cornwall.

Bertrandite appears to be a rare mineral at this locality, insomuch a
successive searches have resulted in the finding of three specimens only
these I collected in 1905.

The crystals are small, the largest measuring about 1 mm. in lengt
They occupy the interstices of masses consisting principally of smal
bright, cubes of pyrite, a {100}, o {111}, with some black tetrahedra
blende, and also a little pale-purple fluor, black, fibrous tourmalin
quartz, and a white, scaly, talcose mineral. The crystals for the mo
part exactly resemble those of rhombic habit from the Cheesewring an
Gold-diggings Quarries, the forms being the same, c {001} and m {110
prominent, a {100} and b {010} small, and f {130} very small. A fe
owing to the absence of b and f, are rhomb-shaped in outline, bein
bounded by an acute angle $mm' = 121° 20'$, others again are six-side
in outline owing to a large development of b. Of the associated minera
bertrandite appears to have been the last formed, with the exception
fluor, which in one case is evidently of subsequent growth.

[1] The orientation and lettering are throughout as in Dana's 'System
Mineralogy,' sixth edition, 1892.

The specimens were collected from a heap of vein-stuff derived from an adit-level (No. 2 cross-cut)[1] then being driven into Kit Hill on the north side, a little to the N.W. of the granite quarry (Sheet XXIX NW, Six-Inch Ordnance Map). The lode ('Quarry Lode'), which is in granite, was at its intersection with a caunter lode very rich in tin and wolfram for a short distance, and from it were obtained many fine specimens of cassiterite in black and very rarely yellowish-red, translucent, well-winned crystals. This lode also contained small quantities of chalcopyrite and mispickel.

Wheal Metal, Breage, Cornwall.

In 1909 I found three somewhat remarkable specimens of bertrandite. Two of these are in a small collection consisting principally of Cornish minerals, formed by the late Sir Clement Le Neve Foster, and presented by him to the Royal School of Mines, South Kensington, and the third is in Mr. W. Semmons's collection. All three specimens are exactly similar in character and were labelled 'Blende from Wheal Vor, Breage, Cornwall.' They show sharp, black tetrahedra of blende, measuring up to 9 mm. along the edge, with o {111} large and bright, and o' {1$\bar{1}$1} small and dull. These blende crystals are attached to a mass consisting principally of yellowish-white, soft, and partially kaolinized orthoclase, dark-green, scaly and nodular chlorite, and a little quartz. Implanted directly on the blende crystals, and occupying cavities in the orthoclase mass are numerous, colourless, platy crystals of bertrandite, elongated in the direction of the a-axis, and showing the forms a {100}, b {010}, c {001}, f {130}, m {110} (fig. 2). The crystals are mostly intergrown and are flattened, effecting lamellar groupings more or less parallel to c, which face possesses the characteristic pearly lustre. There are three distinct cleavages parallel to c {001}, b {010}, and m {110}. Some of the crystals attain a diameter of 5 mm. and have a thickness of 0·7 mm. One of the largest plates has a number of small irregularly placed rectangular pits on the c face, suggesting impressions due to some mineral no longer present. The specific gravity of the crystals is about 2·59.

Thinking there might be other Cornish examples of bertrandite, I looked carefully through the various minerals labelled Wheal Vor,

[1] This and two other adit-levels, one above, and one below, although situated on the north side of Kit Hill were during the recent working designated East Kit Hill Mine; the company making use of an engine which was standing on the old East Kit Hill Mine for the purpose of driving their dressing plant. The workings were abandoned in 1909. They are included in the group of mines on Kit Hill known as Kit Hill Great Consols Mine.

preserved in the British Museum (Natural History) and also in my own collection, and was rewarded by finding three additional specimens. Of the two in the British Museum, one (reg. no. 61384) was purchased in 1886, and the dealer's label describes it as 'Orthoclase and Blende from Trevaunance Mine, St. Agnes, Cornwall.' This locality is, however, obviously wrong, and should be Wheal Metal, Breage, Cornwall, the specimens being practically identical in character with those described above. It shows numerous large, though mostly broken, plates of bertrandite resting on black tetrahedra of blende, with chlorite, and cream-coloured crystals of orthoclase of adularia habit.

The other British Museum specimen is especially interesting and has been referred to by Mr. J. H. Collins in his 'Handbook to the Mineralogy of Cornwall and Devon' (Truro, 1871, part ii, p. 2). Of it he says: 'An interesting specimen of albite, in very peculiar colourless transparent

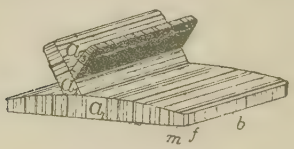

Fig. 1.—Twinned crystal (triplet) of Bertrandite from Gold-diggings Quarry, Cornwall.

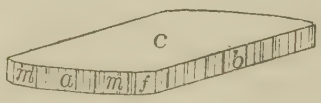

Fig. 2.—Crystal of Bertrandite from Wheal Metal, Cornwall.

twinned crystals, was recently found at Huel Metal, in Breage, in the 135 fathom level, by Capt. G. M. Henty. It is now in the British Museum.' This specimen was presented to the Museum by Captain Henty (an agent at Wheal Metal) in 1870, and was registered at the time as albite; the date of its presentation being ten years previous to Bertrand's original announcement of bertrandite as a new species. I am indebted to Mr. L. J. Spencer for supplying me with the following description of this specimen:

'The small specimen (reg. no. 43938), of less than a cubic inch volume, consists of a matrix of quartz and a black, compact aggregate of fine tourmaline needles. On the free surface are prisms of quartz, small, nodular masses of dark-green chlorite, and a yellowish, clayey material. The bertrandite crystals encrust the quartz crystals, and also form a hollow crust suggesting a pseudomorph after an octahedron possibly of fluor. The order of deposition appears to be tourmaline, quartz, chlorite, bertrandite, chlorite, clay.

'The crystals of bertrandite are white to colourless and transparent, the smaller ones being perfectly water-clear. The forms determined by measurement on the goniometer are: a {100}, b {010}, c {001}, f {130}, m {110}, ϵ {011}. The faces $a\,f\,m\,b$ are striated parallel to their zone-axis, the striations on a being a prominent feature on the twinned crystals. The faces of ϵ are striated parallel to their intersection with b, and c is smooth with a somewhat pearly lustre. The crystals are elongated in the direction of the a-axis, and they range from a fraction of a millimetre to 4 mm. in length in this direction. Simple, twinned, and triplet crystals[1] are present (figs. 3–5), the twin-plane being ϵ (011). The form ϵ was noted only on the twinned crystals, and these are relatively thicker (in the direction perpendicular to the base) than the simple crystals. The angle $\epsilon\underline{b}$ between the faces of adjacent twinned portions was measured as 2° 42′, 2° 38′ (calculated 2° 33′) and the re-entrant angle $\epsilon\underline{\epsilon}$ as 56° 33′ (calculated 56° 36′).

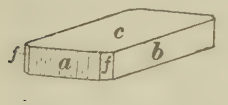

Fig. 3.—Simple crystal.

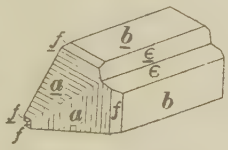

Fig. 4.—Twinned on ϵ (0$\bar{1}$1).

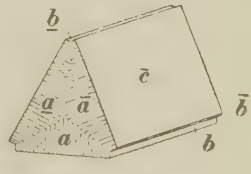

Fig. 5.—Triplet twinned on (011) and (0$\bar{1}$1).

Bertrandite from Wheal Metal, Breage, Cornwall.

'A negative biaxial figure was seen through the face a, the plane of the optic axes being parallel to b (010), that is, parallel to the striations on a. The optic axial angle in oil (of refractive index 1·505) is $2H_a = 90°$ about. The angle between the optic axial planes in adjacent twinned portions is 118°. Specific gravity about 2·59.'

The specimen in my own collection is also from Wheal Metal and was acquired from Mr. F. H. Butler about 13 years ago. It consists of a mamillated mass of cassiterite (wood-tin) measuring about 8 × 6 cm., and is built up of brown, concentric layers which have a fibrous structure, becoming black and distinctly crystallized towards the exterior. The outer surface of the mass is more or less coated with small, nodular aggregates of greenish-grey gilbertite, upon which on one part of the specimen are thickly clustered numerous small crystals of bertrandite,

[1] Very similar twin-crystals of bertrandite from Pisek, Bohemia, have been described by C. Vrba, Zeits. Kryst. Min., 1894, vol. xxiv, p. 112.

and also two colourless prismatic crystals of apatite (one of these was measured and shows the following forms c {0001}, m {10$\bar{1}$0}, a {11$\bar{2}$0}, r {10$\bar{1}$2}, x {10$\bar{1}$1}, y {20$\bar{2}$1}, s {11$\bar{2}$1}), white crystals of orthoclase of adularia habit, and a little, dark-green chlorite.

These bertrandite crystals attain a length of 2·5 mm. and are whitish to colourless, and nearly transparent. The forms determined by measurement are: a {100}, b {010}, c {001}, m {110}, f {130}, and ϵ {011}, both m and f being well developed. The crystals are elongated in the direction of the a-axis and are all twinned on ϵ, most of them showing the thicker of the two individuals extending beyond each side of its fellow, and are thus exactly similar to the twin-crystals from Gold-diggings Quarry described above; others are similar to that shown in fig. 4 of Mr. Spencer's description of the preceding specimen.

Cassiterite in the form of wood-tin was found in considerable abundance, in the year 1866, in the 162 fathom level on Wheal Metal lode west of the Metal Engine Shaft, and its occurrence was described by Captain G. M. Henty.[1] It was associated with ordinary crystallized cassiterite, quartz, chlorite, chalcedony, dolomite, orthoclase, and pyrite. In 1873 the same mineral was found in even larger quantities, in the same lode about 80 fathoms farther east, and at a depth of about 200 fathoms.[2] The Metal lode was entirely in killas and was extraordinarily rich in cassiterite; it also contained small quantities of chalcopyrite and blende.

There can, I think, be no doubt that the above-mentioned specimens of bertrandite with blende labelled Wheal Vor really came from Wheal Metal, the exact locality being confused by the two distinct mines being once included under the same name. Without entering into the history of Wheal Vor and Wheal Metal, it may be pointed out that Wheal Metal, although really a distinct mine worked on lodes to the south and parallel to those of Wheal Vor, formed at one time (1855 to 1877) part of a sett known as Great Wheal Vor. Wheal Vor proper was abandoned about 1848, while Wheal Metal continued working down to 1877.

In conclusion I may say that a careful search on the old burrows of Wheal Metal and Wheal Vor has failed to produce any further specimens.

[1] G. M. Henty, 'On the Occurrence of Wood Tin at the Great Wheal Vor Mines,' Rep. Miners' Assoc. Cornwall and Devon, 1867, p. 55.

[2] W. H. Argall, 'On the Occurrence of Wood-tin in the Wheal Metal Lode at Wheal Vor,' Journ. Roy. Inst. Cornwall, 1873, vol. iv, p. 255.

Mean Quarry,[1] *Constantine, Cornwall.*

Since writing the above notes, I have quite recently, in 1913, found a single small specimen of bertrandite in this granite quarry. The crystals are tabular parallel to *c* (001), and are very nearly square in outline. They show a tendency to parallel grouping, being piled one on another on the basal planes. They attain a length of $2\frac{1}{2}$ mm. in the slightly longer direction of the *a*-axis. The forms present are *a* {100}, *b* {010}, *c* {001}, with very narrow faces of *m* {110}. An interesting feature in connexion with this bertrandite occurrence is that the crystals partially invest long hexagonal crystals of pale-violet apatite, and are therefore of more recent formation than the latter mineral. The other associated minerals are large white crystals of albite, quartz, small hexagonal plates of muscovite, earthy green chlorite, tourmaline, and orthoclase, the whole occupying a cavity in a coarse pegmatite granite.

[1] This quarry is situated a few yards to the west of the houses shown on the maps as Mean Pern (Sheet LXXI SW, Six-Inch Ordnance Map). The spelling 'Mean Quarry' is that given on the Ordnance Maps; in the Home Office List of Quarries, however, it is spelt 'Maen'.

The Meteoric Stones of Baroti, Punjab, India, and Wittekrantz, South Africa.[1]

By G. T. Prior, M.A., D.Sc., F.R.S.

Keeper of Minerals in the British Museum.

[Read June 17 and November 11, 1913.]

The Meteoric Stone of Baroti, Punjab, India.

Fall of the Stone.

In 1912 Mr. N. B. Kinnear, Curator of the Bombay Natural History Society's Museum, brought to me at the British Museum, for identification, a specimen of a supposed meteorite which had been sent to the Bombay Natural History Society by the late General W. Osborn.

General Osborn stated that, in November, 1910, on arrival at his usual winter quarters in the hill station of Kotheir in the Punjab, he visited his friend, the Rajah of Bilaspur, who presented him with a fragment, weighing about a quarter of a pound, of a meteorite which had fallen in daylight at the village of Baroti, in the Bilaspur (Simla) district, one day during the month of September, 1910.[2] General Osborn afterwards visited the locality and was able to procure from the natives a piece of the meteorite weighing $4\frac{1}{4}$ lb., together with several smaller fragments. In a letter to Mr. Kinnear, he supplied the following account of the fall of the stone, as given to him by the natives in answer to inquiries which he made in the villages:—

'At about ten o'clock in the morning, the villagers at Baroti, a village in the Bilaspur (Simla) district, were at work about their fields when

[1] Communicated by permission of the Trustees of the British Museum.

[2] According to a brief account of the meteorite of Baroti by G. Cotter in Rec. Geol. Surv. India, 1912, vol. xlii, p. 273, the stone fell at about 10 a.m. on September 15, 1910.

they were alarmed by a rushing noise overhead. Looking up they saw a meteor approaching them at a great velocity, accompanied by a cloud of light-coloured smoke. The meteorite struck the earth about four hundred yards from their village. On going to the spot they found that it had landed with great force on a sheet of ordinary dark sandstone rock, the face of which, at the point of impact, was broken up for a space of about two feet in diameter, and to a depth of more than an inch. The meteorite itself was broken in pieces on its contact with the rock. The villagers gathered up these fragments, some of which they took to the Rajah of Bilaspur, others they kept themselves, either as curiosities, or probably as objects of superstitious reverence.'

On a second visit to his winter quarters in Kotheir, in March, 1912, General Osborn succeeded in obtaining from the men of Baroti two additional small fragments of the meteorite.

Through the kindness of Mr. Kinnear a fragment weighing 858 grams, and smaller pieces (50 and 25 grams) for analysis, have been presented to the British Museum by the Bombay Natural History Society.

Physical Characters.

The piece weighing 858 grams is a fragment of a stone which was probably three or four times as large. It is half covered with the usual dull black crust, and is sharply pointed at one end, where three fairly flat, crusted surfaces meet. The broken, uncrusted surface is white and shows no sign of brecciation or veining. On close examination, it is seen to be spangled over with small grains of silver-white nickeliferous iron and with bronzy-yellow troilite. Otherwise it is fairly uniform in appearance and only with difficulty can a few chondrules be distinguished. The material is somewhat friable. The specific gravity of the stone was found to be 3·54.

Mineral Composition.

Examined in thin-slices under the microscope, the meteorite is seen to consist of a finely granular aggregate of colourless bronzite and olivine, in which are distributed numerous small particles of nickel-iron and troilite, and a few chondrules not sharply separated from the matrix. With a high power a fair amount of colourless interstitial felspathic material can be detected. It consists of an acid felspar near to oligoclase, as the refraction is about equal to that of the Canada balsam, and, though most particles extinguished uniformly, a few showed faint twin-

striations and one gave symmetrical extinctions about the twin-lamellae of 8°. Of the chondrules, some consist of olivine (polysomatic), but most are of radial fibrous bronzite or of alternating bars of bronzite giving straight extinction and of 'clino-bronzite' giving extinctions generally higher than 20°: in some cases the interspaces between the eccentrically radiating bronzite are filled with the felspathic material.

Method of Chemical Analysis.

In order to avoid the tedious separation of the metallic iron by means of ammonio-mercuric chloride, the following simple method of analysis was adopted. It is probable that an analysis made by this method, when conducted with all care, will give results little less accurate than those obtained by the more complex method involving so many processes in which loss or inaccuracies may occur.

A fragment of the stone, free from crust and as fresh as possible, from 10 to 15 or even 20 grams in weight, is broken up and ground to powder so far as the lumps of metallic iron will allow. The material thus obtained is then separated into attracted and unattracted portions by means of a magnetic comb. After the separation of the coarser grains of metallic iron, the unattracted portion is re-ground and the separation with the magnet repeated several times, so as to extract practically all the metallic iron. In this way the attracted material may contain a considerable amount (from 20 to 30 per cent.) of adhering unattracted material, but it is less disadvantageous that this should be the case than that any appreciable amount of metallic iron should be left with the main mass of unattracted material. The attracted and unattracted portions are then treated as follows:—

(1) *Attracted portion.*—As the material consists of lumps of metallic iron of varying sizes, with adhering non-metallic material, it is inadmissible to separate it into different portions for different determinations; it must be treated as a whole. It is digested on the water-bath with hydrochloric acid of specific gravity 1·06, to which a few cubic centimetres of nitric acid are added. After half-an-hour's digestion the liquid is poured off from the insoluble residue, which is again digested with acid, the operation being repeated until the liquid is no longer coloured by iron. The residue is collected and washed, and is then digested with carbonate of soda to remove the silica liberated from the soluble silicate. This silica is added to that obtained by the evaporation

of the main solution of the iron. After the separation of silica from the main solution, the filtrate is collected in a graduated flask and portions are set aside for the determination of sulphur and phosphorus. In the remainder, the iron, nickel, lime, magnesia, &c., are determined by the usual methods. For the separation of nickel, precipitation of the iron with ammonia, repeated four or even five times, was used.

The total iron obtained in the analysis is due mainly to the metallic iron, but also partly to the troilite and the soluble silicate. To obtain the percentage of metallic iron, therefore, from the total iron there must be deducted an amount sufficient to form sulphide of iron with the sulphur, and an amount corresponding to the ferrous iron in the soluble silicate. The latter may be calculated as the amount sufficient to form an orthosilicate with the silica and magnesia, or, better, may be determined by analysing the soluble silicate in the unattracted material.

(2) *Unattracted portion.*—To the unattracted portion is added the insoluble residue obtained in the analysis of the attracted portion, and the whole is thoroughly mixed.[1] The finely powdered homogeneous material thus obtained can be analysed by the usual methods of rock analysis, and separate portions may be taken for the determination of sulphur, phosphorus, alkalis, chromic oxide, ferrous iron, &c. A portion may also be taken for the determination of the composition of the soluble silicate, or simply for the determination of the proportion of magnesium to iron in it. The small fractional percentage of nickel, which may be obtained in the analysis, is taken as due to nickeliferous iron not removed by the magnet. An amount of iron corresponding to the nickel (as determined by the analysis of the attracted portion) must, therefore, be estimated as metal. In the analysis of the Baroti meteorite no nickel was found in the unattracted material, although two portions were tested; in the analysis of the Wittekrantz stone, only a very small fractional percentage was obtained.

[1] In the analyses of the Baroti and Wittekrantz stones this was not done, and the bulk-analyses were calculated on the assumption that the material adhering to the nickel-iron had the same composition as the main mass of the unattracted portion. The relative amounts of sulphur obtained in the analyses of the attracted and unattracted portions suggest the approximate correctness of this assumption; but any variations would have only a slight effect upon the individual numbers in the bulk-analysis, since the total weight of the unattracted material is more than twenty times as great as that of the adhering material.

Results of the Chemical Analysis of the Baroti Meteorite.

The weight of the attracted portion was 1·4692 gram, that of the unattracted portion 11·3459.

Analysis of the attracted portion.			Analysis of the unattracted portion.		
Fe	... ...	70·38	SiO_2	... ...	43·53
Ni	... ...	6·52	TiO_2	... ...	0·18
Co	... ...	0·24	Al_2O_3	... ...	2·63
SiO_2	... ...	3·42	Fe_2O_3	... ...	0·49
FeO	... ...	2·20 [1]	Cr_2O_3	... ...	0·20
CaO	... ...	0·38	FeO	... ...	15·35
MgO	... ...	3·45	MnO	... ...	trace
FeS S	...	0·34	CaO	... ...	1·96
FeS Fe	...	0·59	MgO	... ...	27·12
Insoluble	...	11·89	SrO	... ...	nil
		99·41	BaO	... ...	nil
			Na_2O	... ...	1·00
			K_2O	... ...	0·05
			P_2O_5	... ...	0·28
			H_2O	... ...	0·19
			FeS Fe	...	4·74
			FeS S	...	2·71
					100·43

The weights taken in the analysis of the unattracted portion were, for main analysis 1·0057 gram, for sulphur 0·6746, for alkalis 0·5100, for phosphorus 0·8250, for ferrous iron 0·6974, for water and chromium 0·4157 gram.

A partial analysis of the soluble silicate, made on 6·0206 grams of the unattracted material, in order to determine the ratio of magnesium to iron, gave the following result, after deducting 12·98 per cent. of FeS and 0·87 per cent. of Fe_2O_3 as determined in the analysis of the unattracted material:—

SiO_2	... ...	31·40
FeO	... ...	20·49
MgO	... ...	32·12

These numbers indicate that the composition of the olivine may be approximately represented by the formula $3Mg_2SiO_4 . Fe_2SiO_4$.

[1] As determined from the analysis of the soluble part of the unattracted material.

Bulk-analysis, i. e. the combined result of the analyses of the attracted and unattracted material:—

		Atomic and molecular ratios.
Fe	8·13	0·1452
Ni	0·75	0·0127
Co	0·03	0·0004
FeS Fe	4·32	0·0772
FeS S	2·47	0·0772
SiO_2	39·68	0·6613
TiO_2	0·16	0·0020
Al_2O_3	2·40	0·0235
Fe_2O_3	0·44	0·0027
Cr_2O_3	0·18	0·0012
FeO	13·99	0·1943
MnO	trace	—
CaO	1·79	0·0320
MgO	24·71	0·6177
Na_2O	0·91	0·0147
K_2O	0·04	0·0004
P_2O_5	0·25	0·0017
H_2O	0·17	0·0094
	100·42	

Mineral composition of the Baroti meteorite, as calculated from the bulk-analysis and the known composition of the olivine ($3Mg_2SiO_4 . Fe_2SiO_4$):—

Molecular ratios.		Percentages.		
147	$Na_2O . Al_2O_3 . 6SiO_2$	7·70		
4	$K_2O . Al_2O_3 . 6SiO_2$	0·22	10·25	Felspar
84	$CaO . Al_2O_3 . 2SiO_2$	2·33		
27	$FeO . Fe_2O_3$		0·63	Magnetite
20	$FeO . TiO_2$		0·31	Ilmenite
12	$FeO . Cr_2O_3$		0·27	Chromite
$\frac{17}{3}$	$\{3Ca_32(PO_4) . CaO\}$		0·56	Apatite[1]?
179	$CaSiO_3$	2·08		
534	$FeSiO_3$	7·03	30·38	Bronzite
2127	$MgSiO_3$	21·27		
675	Fe_2SiO_4	13·77	42·12	Olivine
2025	Mg_2SiO_4	28·35		
772	FeS		6·79	Troilite
1452	Fe	8·13		
127	Ni	0·75	8·91	Nickel-iron
4	Co	0·03		
94	H_2O		0·17	Water
			100·39	

[1] The phosphorus has been attributed to apatite rather than to schreibersite since it was found only in the unattracted material.

The Meteoric Stone of Wittekrantz, South Africa.

Fall of the Stone.

In 1898 a small fragment of a stony meteorite which fell at Wittekrantz, Beaufort West, Cape Colony, was presented to the South African Museum, Cape Town, by Dr. C. E. Piers. In answer to the inquiries made by Dr. G. S. Corstorphine, accounts of the fall were obtained from Mr. J. S. Parker, of Wittekrantz, and Mr. W. F. Savage, who witnessed the event. Mr. J. S. Parker's graphic description of the fall, as given in a letter to Dr. Corstorphine dated April 27, 1900, is as follows:—

'On the 9th of December, 1880, at about 8 a.m., I heard a most unusual noise and saw high in the air a dense stripe of smoke, and as the smoke travelled along, reports came from it like the quick firing of a rifle. The aerolite was travelling in an easterly direction, and at a great pace, for it was very soon out of hearing—only the smoke being visible. I concluded that at each report a piece of the aerolite must have sprung from the main body, as two pieces struck the ground near my house. The one we have got, but the other struck the ground about 200 yards from my dwelling-house. Before it reached the earth, it made a noise like a stone from a sling, only much louder, and that made us notice where it struck ground, which it did with such force as to bruise one end. When picked up it was so hot that it could not be touched with the naked hand and was carried to the house on a flat stone. Mr. Savage and Dr. Stewart were at my place on the morning this happened, and both saw the stone.'

The stone here described as actually seen to fall was presented by Mr. Parker to the South African Museum in 1900, and is referred to by Dr. Corstorphine in the Report of the South African Museum for that year.[1]

Mr. W. F. Savage, in a letter to Miss M. Wilman dated November 14, 1902, gives the following account:—

'The exact date I forget, but it was about eight in the morning. I and Mr. James Parker's brother Jack were busy with a purchase of some wool in front of one of the Kraals at the farm Wittekrantz, when the heat became very intense, and then we heard a rumbling noise proceeding from the direction of the Krantz, and then we heard a rattle as of musketry and the whizzing of bullets, and one particularly large one appeared to be coming our way . . . and passed us with a terrible whiz and fell to earth about 200 yards off. Shortly after, a Kaffir boy who

[1] Report of the South African Museum for 1900, Cape Town, 1901, p. 10.

w it fall by the dust it threw up, ran across and picked it up. He uld not pick it up at first for the heat; however, he managed to bring to the house, and it was even then warm. . . . It fell on a flat stone, d simply crushed the spot it fell on to powder. The moment almost ter the missile passed us the air became normally cool again.'

In a letter to Mr. W. L. Sclater, dated March 28, 1900, Dr. C. E. Piers ated how he obtained the small piece of the meteorite which he pre- ated to the South African Museum in 1898:—

'It was presented to me some time between June, 1882, and April, 85, when I resided at Wagenaar's Kraal in the Nieuweveld, by rs. Parker, the wife of — Parker, of the farm Wittekrantz, District of aufort West. She informed me that the meteorite in question was ought to her at the homestead by a Kaffir herdman, who was throwing from hand to hand, it still being too hot to hold in one hand, and that said he had seen it strike the ground near the homestead, I under- ood some three or four hundred yards away, and as his master was out had brought it to his mistress. Mrs. Parker informed me that some eces had also fallen in an adjoining farm.'

It seems probable from these accounts that two stones at least fell near e farm of Wittekrantz, one of which was seen by Mr. James S. Parker, d is the large stone presented by him to the South African Museum, ile the other was the one seen by Mr. Savage, a fragment of which terwards came into the possession of Dr. Piers.

Both specimens were sent by Dr. Corstorphine to the British Museum r examination. The larger one, after a cast had been made of it, was turned to the South African Museum. The smaller one was retained r investigation, the results of which are given in this paper.

Physical Characters.

The large stone presented by Mr. Parker weighed 4lb. 7oz. From e cast preserved in the British Museum, it appears to be a fairly com- ete stone, covered by the usual fused black crust, except on the edges d corners, where it appears to have been rubbed away to a large tent. The small specimen (113·5 grams) is a broken fragment of larger stone: only small patches of fused crust remain on the unbroken rface. On the fractured surface the stone is seen to be grey and mpact, and shows numerous small particles of nickeliferous iron. roilite is not so obvious, but can be seen in thin veins and patches with lens. One or two fairly sharply defined chondrules are also visible.

The specific gravity of the stone was found to be 3·49.

Mineral Composition.

Under the microscope in thin-slices the meteorite is seen to be very similar in character to the Baroti stone. Small patches of nickeliferous iron and troilite (in less amount) are seen scattered through a matrix consisting of confusedly arranged grains of olivine and enstatite, with a few chondrules of irregular shape and not sharply defined from the rest of the matrix. These chondrules, like those of Baroti, consist mainly of fibrous bronzite. The colourless interstitial material differs from that in the Baroti stone by being for the most part isotropic; and having an index of refraction less than that of Canada balsam.

Chemical Composition.

The analysis was made by the same method as in the case of the Baroti meteorite, excepting that no separate determination was made of the composition of the soluble part of the unattracted material. A fragment weighing about 10 grams was taken. After being powdered and separated with the magnetic comb, this yielded 1·1959 gram of attracted and 8·7383 grams of unattracted material.

Analysis of the attracted portion.		Analysis of the unattracted portion.	
Fe	59·49	SiO_2	44·64
Ni	5·82	TiO_2	0·19
Co	0·13	Al_2O_3	2·76
SiO_2	5·46	Fe_2O_3	0·52
FeO	3·17	Cr_2O_3	0·39
CaO	0·20	FeO	15·76
MgO	5·37	MnO	0·16
FeS { Fe	0·79	CaO	2·31
FeS { S	0·45	MgO	27·58
Insoluble	18·64	Na_2O	1·26
	99·52	K_2O	0·15
		P_2O_5	0·17
		H_2O	0·18
		{ Fe	0·50
		{ Ni	0·05
		{ Fe	2·39
		{ S	1·37
			100·38

From the percentages of FeO, MgO, and SiO_2 in the analysis of the ttracted portion, the composition of the olivine approximates to that of he olivine in the Baroti stone, viz. $3Mg_2SiO_4 . Fe_2SiO_4$.

The weights taken in the analysis of the unattracted portion were, or main analysis 1·0539 gram, for sulphur and phosphorus 0·7325, for lkalis 0·5382, for ferrous iron 0·7337, for chromium 0·9540, for water ·0061 gram.

Bulk-analysis of the Wittekrantz meteorite (combined result of the nalyses of the attracted and unattracted material):—

		Atomic and molecular ratios.
Fe	7·65	0·1366
Ni	0·75	0·0127
Co	0·02	0·0003
FeS Fe	2·20	0·0393
FeS S	1·26	0·0393
SiO_2	41·12	0·6853
TiO_2	0·17	0·0021
Al_2O_3	2·54	0·0249
Fe_2O_3	0·48	0·0030
Cr_2O_3	0·36	0·0023
FeO	14·51	0·2015
MnO	0·15	0·0021
CaO	2·12	0·0380
MgO	25·40	0·6350
Na_2O	1·16	0·0187
K_2O	0·14	0·0015
P_2O_5	0·16	0·0011
H_2O	0·16	0·0089
	100·35	

Mineral composition of the Wittekrantz meteorite as calculated from he result of the bulk analysis and the known composition of the olivine $3Mg_2SiO_4 . Fe_2SiO_4$) is as follows:—

Molecular ratios.		Percentages.		
187	$Na_2O . Al_2O_3 . 6SiO_2$ ...	9·81		
15	$K_2O . Al_2O_3 . 6SiO_2$ ...	0·83	... 11·95	... Felspar
47	$CaO . Al_2O_3 . 2SiO_2$ ...	1·31		
30	$FeO . Fe_2O_3$	...	... 0·70	... Magnetite
21	$FeO . TiO_2$	...	... 0·32	... Ilmenite
23	$FeO . Cr_2O_3$	...	... 0·52	... Chromite
$\frac{11}{3}$	$\{3Ca_3 2(PO_4) . CaO\}$ ...	...	... 0·37	... Apatite[1]?
296	$CaSiO_3$	3·43		
421	$FeSiO_3$	5·56	... 26·89	... Bronzite
1790	$MgSiO_3$	17·90		
760	Fe_2SiO_4	15·50		
2280	Mg_2SiO_4	31·92	... 47·42	... Olivine
393	FeS	...	... 3·46	... Troilite
1366	Fe	7·65		
127	Ni	0·75	... 8·42	... Nickel-iron
3	Co	0·02		
89	H_2O	...	... 0·16	... Water
			100·21	

The most interesting result of the investigation of these two meteoric stones is the demonstration of the close similarity in chemical and mineral composition presented by meteorites, one of which fell in South Africa in 1880 and the other in India in 1910.

As seen in the following table, these meteorites are also very closely related to the recently described[2] chondritic stone which fell at St. Michel, Finland, on July 12, 1910:—

	Baroti.	Wittekrantz.	St. Michel.
Nickel-iron ...	8·91 ...	8·42 ...	8·71
Troilite	6·79 ...	3·46 ...	6·11
Olivine	42·12 ...	47·42 ...	43·22
Bronzite	30·38 ...	26·89 ...	26·25
Felspar	10·25 ...	11·95 ...	14·63

How far this similarity extends to other chondritic meteoric stones is discussed in the following paper.

[1] See footnote, p. 27.

[2] L. H. Borgström, Bull. Comm. Géol. Finlande, 1912, No. 34.

On the remarkable similarity in chemical and mineral composition of chondritic meteoric stones.[1]

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[Read November 11, 1918.]

THE observation of the striking similarity both in chemical and mineral composition of the Baroti, Wittekrantz, and St. Michel meteorites (see the preceding paper) suggested the idea of testing how far such a close relationship applied to other chondritic meteoric stones.

The practical identity in chemical composition of different meteoric stones has been often pointed out. For example, A. E. Nordenskiöld[2] showed in the case of the stones of Erxleben, Lixna, Blansko, Ohaba, Pillistfer, Dundrum, Hessle, Orvinio, and Ställdalen that the percentage chemical compositions differed very slightly if the proportions of the metals, silicon, &c., were considered instead of the oxides. The general resemblance of chondritic stones is also very obvious in thin-sections examined under the microscope; for the most part only some of the so-called crystalline chondrites,[3] such as Hvittis, Pillistfer, Daniel's Kuil, Cléguérec, and Khairpur, distinguishing themselves at all markedly from the rest. It is this close resemblance which has rendered the possible recognition of any periodicity of falls of similar meteorites difficult.[4]

It is the object of the present note to bring into prominence these similarities, since they appears to have been rather obscured than otherwise by the somewhat too elaborate schemes of classification which have been devised. The Tschermak-Brezina classification, which has

[1] Communicated by permission of the Trustees of the British Museum.

[2] A. E. Nordenskiöld, Geol. Fören. Förh. Stockholm, 1878, vol. iv, p. 56; Abstract in Neues Jahrb. Min., 1879, p. 77.

[3] 'Ck' of Brezina's Classification.

[4] See G. Tschermak, Sitz.-Ber. Akad. Wien, 1907, vol. cxvi, p. 1430, and L. Fletcher, 'An Introduction to the Study of Meteorites,' 10th edit., 1908, p. 46.

been generally adopted, is based in the case of chondritic stones almost solely upon physical and structural variations, some of which are of a quite trivial character. A classification of terrestrial rocks upon similar lines would not bear contemplation, when the present embarrassing superfluity of specific rock-names is considered. Even when a terrestrial rock classification is applied to meteorites we find that its effect is to some extent to disguise rather than to emphasize similarities. This is the case with the interesting attempt which O. C. Farrington[1] has made to classify meteoric stones on the same principles as those used for the quantitative classification of igneous terrestrial rocks.[2] The difficulties, however, involved in the chemical analysis of meteoric stones, especially in respect to the apportioning of the total iron between the metallic iron, the troilite, the silicates, &c., are so great, and the methods generally employed of separating the metallic iron by means of copper chloride, mercuric chloride, or iodine are so tedious, that only in the hands of expert and very patient analysts can fairly accurate results be expected. A critical examination of the analyses quoted by Farrington shows in fact that the variations, apart from those of the nickel-iron, by which according to the quantitative system the chondritic stones are divided into groups, are in many cases simply due to errors of analysis involved in the determination of the iron according to its different conditions as to oxidation, &c. Where the percentage of ferrous oxide is higher than the average it will often be found that the iron is low and vice versa. That the amount of metallic iron has been underestimated in the case of the meteoric stones of Ergheo, Mauerkirchen, Long Island, Stavropol, and Zavid is rendered highly probable by merely a cursory examination of the specimens of these meteorites in the British Museum Collection, for they all show quite normally fair amounts of metallic iron upon polished surfaces, whereas the percentages recorded in the analyses are so small as to be either insufficient or very little more than sufficient to form troilite with the sulphur. For such reasons it appears much more probable that where, as is sometimes the case, different analyses of the same stone bring it into different groups, this result is due rather to analytical vagaries than to actual variations in different parts of the stone. What material, for example, could be more homogeneous in appearance than that of the Alfianello stone, yet in the

[1] O. C. Farrington, 'Analyses of Stone Meteorites,' Field Mus. of Natural History, Chicago, 1911, Publication 151, Geol. Ser., vol. iii, No. 9, pp. 195–229.

[2] W. Cross and others, 'Quantitative Classification of Igneous Rocks,' Chicago, 1903.

quantitative classification it falls into two different groups, and could be placed in two more according to the data of two other analyses which have been published.[1]

Objection has been made to the quantitative classification of terrestrial rocks that in some cases it tends to separate far apart rocks which are mineralogically very similar. That it has the same tendency to disguise similarities in the case of meteorites, however, appears to be due not so much to faults in this system as to imperfections in the analytical material to which it has been applied.

Instead of considering the individual percentages of the bulk analyses as is done in the quantitative classification, I have sought to compare the mineral composition of a number of meteoric stones for which this has been determined by analyses of the soluble and insoluble silicates. The results obtained in the case of forty-one chondritic stones are given in the accompanying table (pp. 36, 37).

The table shows the remarkable similarity, if not specific identity, as regards chemical and mineral composition of these particular stones. In the case of these meteorites, when allowance is made for some variation in the amount of nickel-iron, not only are the amounts of the soluble and insoluble silicates remarkably constant, but their actual chemical composition varies very slightly, the proportion of magnesium to iron atoms in the olivine being generally about 3 : 1, and in the bronzite 4 : 1.

In two columns of the table are given the symbols and names of the stones in the Brezina and quantitative classifications respectively as quoted from Farrington's paper. From these it is evident that the structural and physical variations on which the Brezina classification is based have little or no connexion with changes in the chemical and mineral composition; and that in the quantitative classification the groups Estacadose, Parnallose, Pultuskose, Farmingtonose, Castaliose, and Kernouvose are practically identical. Into these groups, changes in the chemical composition relating mainly to the relative amounts of iron and ferrous oxide would bring most of the members of the Traviose and Wacondose groups, including Ergheo and the other stones referred to on p. 34, in the analyses of which too little iron is recorded. These groups account for most of the chondritic meteoric stones of which we have what have been regarded as accurate analyses.

These considerations, therefore, lead to the conclusion that almost all of the chondritic meteoric stones at present known are, apart from some

[1] See C. Friedheim, Sitz.-Ber. Berlin. Akad., 1888, p. 345.

CHEMICAL AND MINERAL COMPOSIT

No.	Name of Meteorite.	Date of Fall.	Specific Gravity.	Percentage of Nickel-iron.	Ratio of Fe to Ni in Nickel-iron.	Percentage of Troilite.	Percentage of Olivine.	Ratio of Mg to Fe Atoms in Olivine.	Percentage of Insoluble Silicates (Bronzite and Felspar).	Ratio of Mg to Fe Atoms in Bronzite.	Percentage of Felspar
1	Ausson	Dec. 9, 1858	3·54	10	9	4	45	3	37	4	
2	Bachmut	Feb. 15, 1814	3·56	6	4	6	43	2	41	4	
3	Baldohn	April 10, 1890	3·79	18	—	6	37	3	38	4	
4	Baroti	Sept. 15, 1910	3·54	9	11	7	42	3	40	4	
5	Beaver Creek	May 26, 1893	—	17	10	5	37	3½	40	5	
6	Cape Girardeau	Aug. 14, 1846	3·67	18	11	6	35	3	41	5	
7	Carcote	(Known since 1888)	3·47	10	10	6	40	2½	41	4	
8	Chantonnay	Aug. 5, 1812	—	8	6	6	42	3	41	4	
9	Cléguérec (Kernouvé)	May 22, 1869	3·75	20	12	6	35	3	40	4	
10	Dhurmsala	July 14, 1860	3·40	8	4½	6	48	4	34	4	
11	Estacado	(Found in 1902)	3·63	14	9	4	41	2	42	4	
12	Farmington	June 25, 1890	—	8	7	5	46	3	41	3	
13	Hessle	Jan. 1, 1869	3·74	19	8	5	42	3	33	4	
14	Honolulu	Sept. 27, 1825	—	4	2	6	48	2	38	4½	
15	Khetri	Jan. 19, 1867	3·68	18	—	5	35	3	42	4	
16	Lesves	April 13, 1896	3·57	8	8	6	46	2½	38	3	
17	Linn County	Feb. 25, 1847	—	10½	9	6	42	3	41	3	
18	Lixna	July 12, 1820	3·73	15	8	6	39	2½	38	5	
19	Lundsgård	April 3, 1889	3·61	12	5	6	41	3	39	4	
20	Makariwa	(Found in 1879)	—	5	4	6	49	3	39	3	
21	Meuselbach	May 19, 1897	3·47	8	7	8	39	2½	38	4	
22	Mezö-Madaras	Sept. 4, 1852	—	10	5	6	42	3	40	3	
23	Modoc	Sept. 2, 1905	3·54	5	10	4	46	3	44	4	
24	Muddoor	Sept. 21, 1865	—	9	7	4	44	3	41	3	
25	Nerft	April 12, 1864	—	6	4	5½	46	2½	39	4	
26	Rakovka	Nov. 20, 1878	3·58	7	4	6	44	3	41	4	
27	Richmond	June 4, 1828	3·37	8	7	4	46	4	42	3	
28	St. Christophe	Nov. 5, 1841	—	9	4	7	43	3	40	4	
29	St. Denis-Westrem	June 7, 1855	—	8	6	5	46	2½	39	4	
30	St. Michel	July 12, 1910	3·56	9	11	6	43	3	41	4	
31	Searsmont	May 21, 1871	3·70	15	10	3	43	3	39	3	
32	Sevrukovo	May 11, 1874	3·50	16	8	5	48	4	31	4	
33	Shelburne	Aug. 13, 1904	3·50	8	10	5	45	3	41	4	
34	Tennasilm	June 28, 1872	3·53	7	5	6	44	2	42	4	
35	Tjabé	Sept. 19, 1869	—	14	10	6	40	3	40	5	
36	Tourinnes-la-Grosse	Dec. 7, 1863	3·61	12	5	6	41	3	39	4	
37	Utah	(Found in 1869)	3·66	17	11	5	40	3	36	5	
38	Utrecht	June 2, 1843	3·61	9	—	5	43	3	42	3	
39	Winnebago County	May 2, 1890	3·80	19	14	6	36	4	38	4½	
40	Wittekrantz	Dec. 9, 1880	3·49	8½	10	3½	47	3	39	4	
41	Zomba	June 25, 1899	3·54	8½	7	5	42	3	44	4	

CHONDRITIC METEORIC STONES.

mbol in zina's ssi- tion.	Name in Quantitative Classification.	Analyst.	Reference.
	Pultuskose	A. A. Damour	C. R. Acad. Sci. Paris, 1859, **49**, 31
	Castaliose	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 18
	—	E. Johanson	Neues Jahrb. Min., 1892, i, 104
or Ro	—	G. T. Prior	Mineral. Mag., 1913, **17**, 22
	Pultuskose	W. F. Hillebrand	Amer. Journ. Sci., 1894, **47**, 430
	Farmingtonose	S. L. Penfield	Amer. Journ. Sci., 1886, **32**, 230
	Parnallose	W. Will	Neues Jahrb. Min., 1889, ii, 177
	—	C. Rammelsberg	Zeits. Deutsch. Geol. Ges., 1870, **22**, 889
	Kernouvose	F. Pisani	C. R. Acad. Sci. Paris, 1869, **68**, 1489
	Pultuskose	S. Haughton	Proc. Roy. Soc. London, 1866, **15**, 214
	Estacadose	J. M. Davison	Amer. Journ. Sci., 1906, **22**, 59
	Farmingtonose	L. G. Eakins	Amer. Journ. Sci., 1892, **43**, 66
	Pultuskose	G. Lindström	K. Svenska Vet. Akad. Handl., 1870, **8**, No. 9
	—	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 1
	Pultuskose	D. Waldie	Journ. Asiatic Soc. Bengal, 1869, **38**, 2, 252
	Parnallose	A. F. Renard	Bull. Acad. Roy. Belg., 1896, **31**, 654
	—	C. Rammelsberg	Monatsber. Akad. Berlin, 1870, **70**, 457
	Pultuskose	A. Kuhlberg	Archiv Naturk. Dorpat, 1867, **4**, 1
	Parnallose	O. Nordenskjöld	Geol. Fören. Förh., 1891, **13**, 470
	—	L. Fletcher	Mineral. Mag., 1894, **10**, 287
	Estacadose	G. Linck	Ann. Naturhist. Mus. Wien, 1899, **13**, 103
	Estacadose	C. Rammelsberg	Zeits. Deutsch. Geol. Ges., 1871, **23**, 734
	Castaliose	W. Tassin	Amer. Journ. Sci., 1906, **21**, 359
	—	F. Crook	Inaug.-Diss., Göttingen, 1868, 33
	Estacadose	A. Kuhlberg	Ann. Phys. Chem. (Pogg.), 1869, **136**, 448
	Parnallose	P. Grigoriew	Zeits. Deutsch. Geol. Ges., 1880, **32**, 417
	Pultuskose	C. Rammelsberg	Monatsber. Akad. Berlin, 1870, **70**, 440
	Pultuskose	A. Lacroix	Bull. Soc. Sci. Nat. Ouest France, 1906, **6**, 81
	Pultuskose	C. Klement	Bull. Mus. Hist. Nat. Belg., 1886, **4**, 280
or Ro	Estacadose	L. H. Borgström	Bull. Comm. Géol. Finl., 1912, No. 34
	Pultuskose	J. L. Smith	Amer. Journ. Sci., 1871, **2**, 200
	—	A. Eberhard	Archiv Naturk. Dorpat, 1882, **9**, 115
	Pultuskose	L. H. Borgström	Trans. Roy. Astron. Soc. Canada, 1904
	—	G. Schilling	Archiv Naturk. Dorpat, 1882, **9**, 95
	—	E. H. Baumhauer	Archiv. Néerl., 1871, **6**, 305
	Parnallose	F. Pisani	C. R. Acad. Sci. Paris, 1864, **58**, 169
	Pultuskose	S. L. Penfield	Amer. Journ. Sci., 1886, **32**, 228
	Farmingtonose	E. H. Baumhauer	Ann. Phys. Chem. (Pogg.), 1845, **66**, 465
	—	L. G. Eakins	Amer. Journ. Sci., 1890, **40**, 319
	—	G. T. Prior	Mineral. Mag., 1913, **17**, 28
	—	L. Fletcher	Mineral. Mag., 1901, **13**, 1

variation in the amount of nickel-iron, practically identical in chemical and mineral composition, the identity extending in the main even to the chemical composition of the olivine and pyroxene.

The type to which most chondritic meteoric stones approximate has in round numbers the following percentage mineral composition :—

Nickeliferous Iron (in which Fe : Ni is about 10) ...	9
Troilite	6
Olivine (in which Mg : Fe = 3)	44
Bronzite (in which Mg : Fe = 4)	30
Felspar (Oligoclase)	10
Chromite, &c.	1
	100

How far this may be too wide a generalization can only be definitely shown by analyses of chondritic stones not hitherto examined and by new accurate analyses to replace many of the older ones; and for this purpose analyses made with all care by the simple time-saving method described in a previous paper (p. 24) might suffice.

(1) *The crystal-habit of Topaz from New Brunswick, Canada.* (2) *A method of silvering crystal-faces for giving improved reflections on the goniometer.*

By H. V. Ellsworth.

Department of Mineralogy, University of Toronto, Canada.

[Communicated by Professor T. L. Walker, and read June 17, 1913.]

IT is only recently that the mineral topaz has been found in any considerable quantity in Canada. Previous to the discovery of the topaz of York County, New Brunswick, in 1911, it was distinctly a rarity among Canadian minerals and had never been found crystallized in any Canadian locality. The above-mentioned district, however, has yielded both the massive and crystallized varieties in fair abundance and some fairly perfect crystals have been obtained for measurement.

The first topaz reported from Canada appears to have been of somewhat doubtful authenticity. It is stated that: 'At the London Exhibition, 1862, Mr. McDonald exhibited two topazes (?) from Cape Breton, one in the rough, and the other, which had been cut at Pictou, half an inch in length and of a yellow colour, the variety peculiar to Brazil, which leads to the inference that these stones may have been citrine or artificially decolorized smoky quartz, and not the true mineralogical topaz.'[1]

In 1896 two rolled pebbles of topaz were obtained from the gravel of a small river west of Jasper House in the Rocky Mountains of Alberta. Both were transparent. The one measured $20 \times 20 \times 13$ mm. and was of a light bluish-green colour, while the other measured $25 \times 15 \times 15$ mm. and had a faint orange-yellow tinge.[2]

In 1911 E. S. Moore found topaz quite abundant in thin-sections of hornblende-syenite from the eastern shore of the narrows of Sturgeon Lake, Ontario. It was observed as a colourless mineral filling in spaces

[1] Report of the Geological Survey of Canada, 1887-8, vol. iii, p. 66 S.

[2] Report of the Geological Survey of Canada, 1896, vol. ix, p. 18 R.

between the felspars and in places apparently partly replacing them. Associated with it were considerable quantities of fluorite and titanite with some tourmaline and apatite and other products of pneumatolytic action.[1]

The latest and by far the most important occurrence of topaz in Canada, however, is in the district around the confluence of Burnt Hill Brook and the South-West Branch of the Miramichi River in York County, New Brunswick (Long. 66° 48′ W., lat. 66° 34′ N.). Geologically, the region is rather simple. Great batholiths of granite have intruded slate which is supposed to be of Cambro-Silurian age. Near the contact, the slate has been fissured and quartz-veins have been formed by the action of the intrusive granite. For many years it had been known that these quartz-veins carried small quantities of molybdenite, but the presence of other minerals apparently had never been reported. In 1910 Professor T. L. Walker visited the district to examine the molybdenite deposits in behalf of the Mines Branch, and discovered that many of the veins carry considerable quantities of wolframite besides the small and unimportant amounts of molybdenite.[2]

In the winter of 1910 Mr. R. A. A. Johnston noted the presence of topaz in specimens of ore from this locality. The association of the minerals wolframite, molybdenite, and topaz suggested the possibility of finding tin-stone also, and led to a further examination of the district by R. W. Brock the following summer. As a result, small quantities of cassiterite were actually found in greisen associated with the quartz-veins. The quartz-veins themselves were found to contain considerable quantities of topaz, both massive and as crystals in vugs and druses, besides wolframite and molybdenite and a little fluorite.[3]

At the suggestion of Dr. Walker, the material collected by him from this locality was examined by the writer with the object of finding crystals suitable for measurement.

The massive topaz appears in considerable quantity associated with quartz, wolframite, and a little molybdenite. In this form it is almost invariably covered by a brown coating of iron oxide, but on a fresh fracture is usually more or less milky in colour. The quartz is somewhat less stained and has a fresher appearance. Crystals are common

[1] Twentieth Report of the Ontario Bureau of Mines, 1911, p. 155.

[2] Summary Report of the Mines Branch, Ottawa, 1910, p. 65. Also, Economic Geology, 1911, vol. vi, p. 396.

[3] Canadian Mining Journal, No. 17, Sept. 1, 1911; reprinted in Summary Report Geological Survey of Canada, 1911, p. 13.

lining vugs, and range in size from microscopic dimensions up to 2 cm. in diameter, with by far the greater number less than 5 mm. in diameter. The larger ones are comparatively rare and are imperfect and unsuitable for measurement.

The crystals are usually more or less stained also, and often contain minute fractures into which the iron oxide has penetrated. The majority are somewhat cloudy or milky, but some perfectly clear, colourless and transparent specimens of small size were obtained. The crystal-faces are often well developed, but the domes and pyramids more particularly sometimes appear to have suffered more or less corrosion and thus have become dull or rough. The edges of the smaller faces also are apt to be somewhat rough and rounded.

Twelve of the best crystals, varying in size from $1 \times 1{\cdot}5 \times 1$ mm. to $3{\cdot}5 \times 5 \times 5$ mm., were selected and measured on the Goldschmidt two-circle goniometer. The following sixteen forms were found definitely developed, doubtful and vicinal forms having been omitted.

Table of Forms.

Crystal No.	$M = \infty = (110)$	$l = \infty 2 = (120)$	$f = 01 = (011)$	$u = \frac{1}{2} = (112)$	$i = \frac{1}{3} = (113)$	$c = 0 = (001)$	$m = \infty \frac{3}{2} = (230)$	$o = 1 = (111)$	$x = \frac{1}{3}\frac{2}{2} = (123)$	$y = 02 = (021)$	$d = 10 = (101)$	$\mu = \infty 5 = (150)$	$b = 0 \infty = (010)$	$\pi = \infty \frac{5}{2} = (250)$	$g = \infty 3 = (130)$	$n = 4 = (140)$
1	+	+	+	+												
2	+	+	+	+												
3	+	+	+	+	+											
4	+	+	+	+	+											
5	+	+	+	+	+	+										
6	+	+	+	+	+	+	+									
7	+	+	+	+	+	+	+									
8	+	+	+	+	+	+	+	+								
9	+	+	+	+	+			+	+							
10	+	+	+	+	+	+	+	+	+							
11	+	+	+	+	+	+	+	+		+						
12	+	+	+	+	+	+		+		+	+	+	+	+	+	+

The forms have been arranged in the table in the order of their frequency of occurrence.

It might be mentioned that, among the doubtful forms, one very narrow but quite distinct prism-face was observed which, though it gave no signal, admitted of being read fairly accurately by maximum illumina-

tion, and was found to approximate very closely to the form $\infty \frac{5}{4} = (450)$.

The character of the signals, on the whole, was such as to preclude any very accurate calculation of the axial ratios. The value calculated from seven of the best faces on crystal 12 giving 'fair' signals was—

$$p_0 : q_0 : r_0 = 1{\cdot}8073 : 0{\cdot}9557 : 1$$
$$(\text{or} \quad a : b : c = 0{\cdot}5288 : 1 : 0{\cdot}9557)$$

which is high as compared with Goldschmidt's calculated value of—

$$p_0 : q_0 : r_0 = 1{\cdot}8049 : 0{\cdot}9539 : 1$$
$$(\text{or} \quad a : b : c = 0{\cdot}5285 : 1 : 0{\cdot}9539).$$

The crystals examined may be divided into two general classes according to habit.

Type I.—The simplest form of this type is represented by crystal 1 (fig. 1) in which the brachydomes $f = 01 = (011)$ are enormously developed, exceeding in size any other terminal faces which may be present, and always accompanied by the pyramid $u = \frac{1}{2} = (112)$. The unit prism $M = \infty = (110)$ and the prism $l = \infty 2 = (120)$ are also invariably present, the latter almost always exceeding the former in development and usually exhibiting vicinal striations, while the former is usually a better reflecting face and is less often striated. Other prism forms are relatively rare and when they do occur are only slightly developed. In addition to the forms mentioned, the base $c = 0 = (001)$ and the pyramid $i = \frac{1}{3} = (113)$ are of fairly common occurrence, and other pyramids as $o = 1 = (111)$ and $x = \frac{1}{3}\frac{2}{3} = (123)$ may appear but are rare. All these latter forms, however, are developed only to a comparatively small extent.

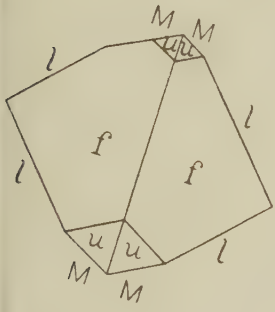
Of the twelve crystals measured, ten were of the general type represented by fig. 1, so that this may be considered the commonest and most characteristic habit for crystals from this locality.

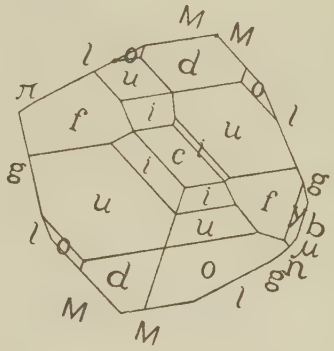
The simpler forms of this type are replicas in habit of some very large specimens of gem topaz from Japan in the collection of the University of Toronto. They are also comparable to the topaz from Altenberg figured by Hintze (Handbuch der Mineralogie) after Groth.

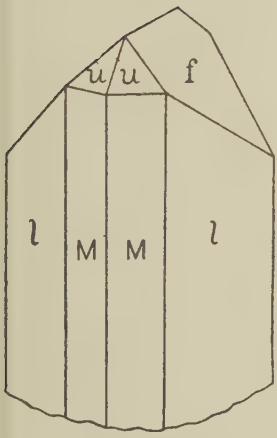
Type II.—The remaining two crystals 11 and 12, and another which could not be measured accurately, were of the general habit represented by fig. 2 (crystal 12), in which all the characteristic forms of type I (M, l, f, u) are retained, but the domes are much reduced in relative size and are accompanied by a greater number of pyramids with correspondingly larger development. Several additional prism forms along with the brachypinacoid also appear.

As the characteristic forms of type I persist on crystals of type II it

would appear that habit II is merely an elaboration of habit I by the addition of more pyramids and prisms and consequent reduction in development of the forms of type I. This is borne out by the fact that forms which are intermediate between the two types occur, as may be







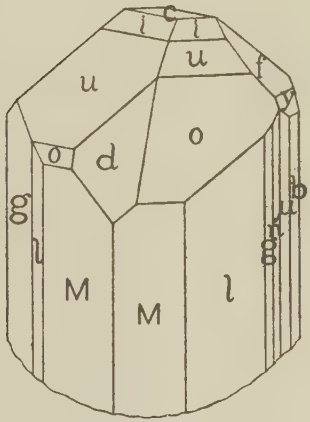


Fig. 1. Fig. 2.

Crystals of Topaz from York County, New Brunswick.

seen from the table, e.g. crystals 9 and 10, in which the domes are somewhat reduced and additional forms appear. Thus, a sufficient number of crystals might yield a complete series, beginning with the

simple type I and with the number of forms gradually increasing until type II or a still more complex type was reached.

(2) *A method of silvering crystal-faces for giving improved reflections on the goniometer.*

In the course of measuring the crystals it was found that many of the faces, particularly the pyramids and domes, were so dull as to give very unsatisfactory reflections. In some cases, indeed, though the faces were well developed, no signal whatever could be obtained. As a possible remedy, the idea of plating the crystals with a thin, uniform film of silver by chemical means suggested itself to the writer and led to some experiments in that direction. As the external surface of the silver film would be the reflecting medium in this case, the methods used in silvering astronomical mirrors might be expected to best suit this requirement. After some experimenting with the various methods used in astronomical work, the Brashear process,[1] in which an ammoniacal solution of silver nitrate is reduced by a sugar solution, was adopted as being the quickest and most satisfactory.

The crystals were first cleared of iron oxide by treatment with acid. All traces of grease were removed with potash and alcohol, so that distilled water would wet the whole surface of the crystal uniformly. This thorough cleaning of the crystal is the point upon which the success of the whole process chiefly depends, as the slightest greasiness will prevent the deposition of silver as an adherent film. After cleaning, the crystals were mounted in the usual way, a pair of chemically clean forceps being used to avoid contamination by grease.

The mounted crystals were then suspended by a piece of pasteboard over a small evaporating dish containing the silvering solution so that the crystals were immersed just up to the mounting-wax. A sufficiently thick coating was obtained in from three to ten minutes, depending on the temperature and the amount of reducing solution used. The crystals were then removed, rinsed and dried, and were ready for measurement.

If the crystals are left in the solution too long the coating loses its brilliancy and becomes dull grey or black. They should be removed as soon as opaque and while still bright.

[1] Astrophysical Journal, 1895, vol. i, p. 252. The writer is indebted to Prof. Chant of the Department of Astro-Physics for a reference to a very comprehensive review of the various modern silvering methods, including Brashear's process, by H. D. Curtis in the 'Publications of the Astronomical Society of the Pacific,' San Francisco, 1911, vol. xxiii, No. 135.

By mounting the crystals before silvering, subsequent handling of the rather delicate silver film is avoided, and moreover, much better results are obtained than if the crystals are simply placed in the bottom of the dish and the silvering solution poured over them.

The results obtained were very satisfactory. The advantages of silvering the crystals may be summed up as follows:

1. The amount of light reflected from the crystal-faces is greatly increased. Hence very small, dull, or rough faces, which ordinarily are hard to locate and may easily be overlooked, are much more readily seen when silvered.

2. In cases where the face is not too rough, but simply dull, the signal usually appears to be improved in brightness and distinctness of outline.

3. As the crystal is rendered opaque by the silver coating, light cannot be reflected through the crystal from faces opposite the one being read. This, and the ease with which the faces are seen owing to their great luminosity, makes the reading of the crystal much less trying to the eyes of the observer.

4. Theoretically, the accuracy of the readings should not be affected, as the coating is excessively thin and very uniform. As a matter of fact, in the case of some of the crystals with dull faces and very poor signals it was found that the silvering resulted in more nearly correct readings due to the improvement in the signals.

In view of the success of these silvering experiments with topaz, it would appear that the method might be extended to other transparent mineral crystals in cases where silvering would be advantageous.

In conclusion, the author wishes to express his sincere thanks to Dr. T. L. Walker and Mr. A. L. Parsons of the University Department of Mineralogy for their interest and advice in the work.

A new stereographic protractor.[1]

(*With Plate IV.*)

By G. F. Herbert Smith, M.A., D.Sc., F.G.S.

Assistant in the Mineral Department of the British Museum.

[Read March 11, 1913.]

IN the stereographic projection (fig. 1) $ABA'B'$ is the primitive circle, having the same radius a as the corresponding sphere; $ATA'T'$ is the circle representing a great circle on the sphere inclined at an angle θ to the plane of the projection; O and C are the centres of the primitive circle and the circle $ATA'T'$ respectively. CO are joined and projected both ways to meet the circles as shown. Then we have the following simple relations:—

$$CO = a \cot \theta, \quad OT = a \tan \frac{\theta}{2}, \quad OT' = a \cot \frac{\theta}{2}, \quad \text{and} \quad CA = a \operatorname{cosec} \theta.$$

By means, therefore, of a scale,[2] which is graduated on the one side of the zero according to the tangent of the angle and on the other according to the tangent of half the complement of the angle, the points T and C are at once read off, and the corresponding circle is readily drawn so long as its radius is not too large.

When $\theta = 45°$, $OC = a$; C then lies on the primitive circle, and coincides with B. As the azimuthal angle grows larger the corresponding radius rapidly increases in length, and recourse must be had to a beam-compass, and ultimately to a flexible ruler. Unless the scale of the stereogram is small, the centres of the circular arcs passing near the pole of the projection lie at an inconvenient distance outside the primitive circle, and it is probably for that reason that Penfield[3] selected as radius

[1] Communicated by permission of the Trustees of the British Museum.

[2] Cf. A. Hutchinson, 'On a protractor for use in constructing stereographic and gnomonic projections of the sphere.' Min. Mag., 1908, vol. xv, pp. 93–112.

[3] S. L. Penfield, Amer. Journ. Sci., 1902, ser. 4, vol. xiv, p. 251.

of the primitive circle 7 cm., while Hutchinson[1] recommended much the same size, viz. 2½ inches (6·35 cm.). The author, on the other hand, is of opinion that this scale, while no doubt admirably suited to teaching purposes, is too small for the convenient discussion of complex crystals, and prefers to follow Fedorov[2] and use a primitive circle of radius 10 cm. Its size is not inconvenient so long as none of the drawing operations need be conducted far outside it; but to achieve this object, some means other than the ordinary method of compasses must be found for constructing circles corresponding to great circles of azimuthal angle ranging from 45° to 90° measured from the plane of the projection.

The curved ruler devised by Fedorov and Wulff[3] for drawing flat circular arcs consists very simply of a stiff spring, which is bent by

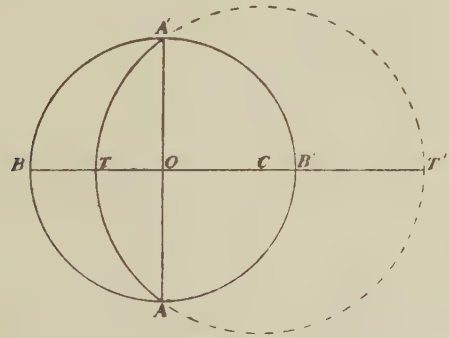


Fig. 1.

a wide two-pronged fork arrangement pushing it against two fixed pins, and returns to its original flat shape by its flexural elasticity, the distance between the prongs being about three-quarters or so that between the pins. The apparatus was afterwards modified[4] by the addition of a scale, which was graduated to give the azimuthal angle to which the particular arc corresponded, the range extending from 0° to 25°, measured from the pole of the projection.

[1] A. Hutchinson, loc. cit., p. 94.
[2] E. S. Fedorov, Zeits. Kryst. Min., 1893, vol. xxi, p. 622.
[3] E. S. Fedorov, Zeits. Kryst. Min., 1893, vol. xxi, p. 618. G. Wulff, ibid., p. 253. Vide also S. L. Penfield, Amer. Journ. Sci., 1901, ser. 4, vol. xi, p. 138.
[4] E. S. Fedorov, Zeits. Kryst. Min., 1902, vol. xxxvii, p. 142.

It will be noticed that this device does not fill the whole range from 45° to 90°; moreover, the curve for a particular reading of the scale differs sensibly according as the spring is being pushed or is returning by its own elasticity, and the curves of greater curvature are not even approximately circular. The curve assumed by a bent spring was first studied by Bernoulli,[1] who worked out its principal properties, and gave it the name *elastica*. The first approximation to it is the harmonic curve or curve of sines, and the curvature is constant only for very small amounts of bending. The curve of the flexible ruler described above is really composed of three separate elasticas, the outer two of which are similar; the curvature is by this means maintained more uniform than if the spring were bent by a central push in the way that an archer bends his bow.

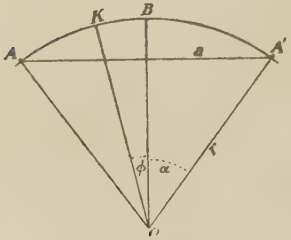


Fig. 2.

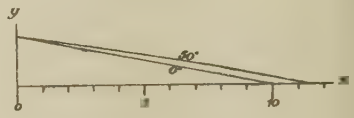


Fig. 3.

The problem considered by the author was the practicability of obtaining more regular curvature, even for considerable amounts of bending the spring, by varying its flexural rigidity, or in other words its thickness.

Fig. 2 shows a spring bent into the form of a circle of radius r by a central push at B against two fixed pins A and A', distant $2a$ apart. K is any point on the spring between A and B. O, the centre of the circle, is joined to the points A, A', B, K. The angles AOB, KOB are α and ϕ respectively; the thickness of the spring at K is y, and KB, the distance of K from the centre of the spring measured along it, is x.

Then $x = r\,\phi$, and $r = a$ cosec α.

By taking moments about K we obtain the equation

$$yc = Qr^2 \sin(\alpha - \phi), \text{ or } Qa^2 \frac{\sin(\alpha - \phi)}{\sin^2 \alpha},$$

[1] J. Bernoulli, 'Sur la force et la courbure des lames élastiques.' Mém. Acad. Berlin, 1766.

Q being the pressure exerted at the pins A and A', and finally we have

$$y = y_0 \frac{\sin\left(\alpha - \frac{x}{a} \cdot \sin\alpha\right)}{\sin\alpha},$$

y_0 being the thickness at the middle point B.

We see that, since the function on the right-hand side is not independent of α, the law of thickness for uniform curvature is not constant for different curvatures. Fig. 3 illustrates the extent of this variability, the curves representing the relative thickness for the values 0° and 50° of α. The angle α, it may be noted, is the azimuth of the corresponding great circle measured from the pole of the projection. Since the curves lie close together, an approximate solution of the problem, sufficiently accurate for graphical purposes, is obtainable by using a spring corresponding in shape intermediately to the curves depicted.

In the instrument as designed (Plate IV) a multiple spring (*a*) composed of a series of clock springs of suitable lengths, pinned together, is used instead of a single spring of varying thickness, because the latter would have been so much less readily obtainable, and the result is much the same. Screw-grips (*b*) are employed in place of rivets, because the holes required for the latter seriously disturb the rigidity of the springs at those points; they are not screwed too tightly, because a little play is necessary to prevent kinking in the outer spring giving the actual trace required; and they are cut away in front so as not to interfere with the passage of the pen or pencil. The pushing-piece (*c*) is provided with a clamp and fine adjustment of the usual pattern, and carries a scale giving the azimuth of the corresponding great circle, the range extending from 40° to 90°. In using the scale, it is, of course, necessary to allow for the thickness of the pen or pencil used. The fixed pins against which the spring impinges are square in section, the distance between the inner corners being 20 cm. On the opposite side of the frame the bevelled edge carries two scales, of the kind mentioned above, viz. one of tangents of half the complement of the angle, from 0° to 90°, giving the position of T' (fig. 1), and the other of tangents of the angle, from 0° to 50°, giving the position of C, the unit being 10 cm. and the scales being graduated to degrees. Since the range of the spring-ruler extends from 40° to 90°, the two methods overlap between 40° and 50°. With this stereograph the sheet of paper used need not be much larger than the stereogram itself.

It may be remarked that theoretically better results would be given by a double pusher after the pattern used by Fedorov and Wulff, but the

mechanical construction would have been immensely complicated owing to the necessity of maintaining the centre of the spring in the line at right angles to that joining the two pins. Moreover, it is advantageous to have a rigid connexion between the spring and the pushing piece.

The frame is constructed of gun-metal, except for the fixed pins, which are of steel, and the scales are silvered. The instrument was made for the Mineral Department of the British Museum by Messrs. J. H. Steward, Limited, 457, West Strand, London, W.C.

A calcium-iron Garnet from China.

By J. B. Scrivenor, M.A., F.G.S.

Geologist to the Federated Malay States Government.

[Read November 11, 1913.]

DURING the earlier half of 1913 Mr. San Ah Wing, a Chinese gentleman residing in Kuala Lumpur, sent me three concentrates of sand for examination. It was thought at first that they came from some part of the Federated Malay States, but the locality proved to be the Yong Choon district of the province of Kwang Tung, China. No information concerning the geology of this district was obtainable, but the association of minerals in the concentrates suggests that they were washed out of detritus derived from calcareous rocks.

The concentrates may be briefly described as follows:—

1. A pale-green sand containing a pale-green, optically isotropic mineral as the chief constituent, a bright-green carbonate of copper, calcite, and a colourless, apparently biaxial mineral that was not determined.

2. A brownish sand containing an isotropic mineral like that in No. 1, but iron-stained and not quite the same colour, a little of the carbonate of copper, and a little quartz.

3. A pale-yellow sand, the chief mineral in which is optically isotropic and of a pale-yellow colour. Tremolite and an undetermined mineral are also present.

The isotropic mineral in No. 3 was found to be partially decomposed by hot hydrochloric acid; but the isotropic mineral in Nos. 1 and 2 was quickly and completely decomposed when reduced to powder and heated with hydrochloric acid, silica being liberated. Cold acid also attacked the mineral.

In No. 1 some grains were detected showing crystal faces, so this concentrate was selected for a thorough examination of the mineral. The copper carbonate and calcite were removed by weak hydrochloric acid. This had a slight effect on the isotropic mineral, liberating a little

silica on the surface, which was removed by rubbing and washing the grains under water.

Microscopical examination showed that a practically pure sample of the isotropic mineral had been thus obtained. The majority of the grains were pale olive-green, but some were brownish. One minute grain, which was preserved in Canada balsam as a microscope preparation, was found showing very clearly the form of the rhombic-dodecahedron {110}. Other grains were found showing crystal faces suggesting the same form, and one grain showed a face that might belong to {211} or {321}. The specific gravity of the cleaned sand was found to be 3·69, and analysis gave:—

Silica (SiO_2)	40·26 per cent.
Total iron as Fe_2O_3	28·62
Alumina (Al_2O_3)	2·61
Lime (CaO)	28·29
Magnesia (MgO)	trace
Loss on ignition	0·94
	100·72

The composition of the isotropic mineral in No. 2 is much the same as the above. That in No. 3, examined for me by Mr. W. R. Jones, contains more alumina and less iron and silica.

The lack of double refraction, the crystalline form, chemical composition, specific gravity, and colour all point to this mineral being a calcium-iron garnet, or andradite. It differs from known garnets, however, in being completely and quickly decomposed by hydrochloric acid without previous ignition, and on that account it calls for this brief description.

REVIEWS.

Igneous Rocks. Vol. II, Description and Occurrence. By Joseph P. Iddings. Pp. xi + 685, with 20 text-figures and 8 maps (5 coloured). (New York: John Wiley & Sons; London: Chapman & Hall. 1913. Price 25*s.* 6*d.* net.)

The first volume of this important treatise appeared in 1909, and was reviewed in this Magazine, vol. xv, p. 331. The second and concluding volume is divided into two parts of equal length, the first dealing with the systematic description of igneous rocks, and the second with their occurrence, or rather geographical distribution. The set of three handsome volumes (including the companion volume on rock-forming minerals by the same author) extends to 1800 pages and forms an indispensable compendium of petrography, although including only the rocks of igneous origin.

We are glad to find that the six main divisions of igneous rocks devised for the purposes of description are based fundamentally on mineralogical composition, namely 'Rocks characterized by':

1. Preponderance of quartz.
2. Quartz and felspar.
3. Felspars with little or no quartz or felspathoid minerals.
4. Felspars and felspathoid minerals.
5. Felspathoid minerals.
6. Chiefly 'mafic'[1] minerals [i.e. pyroxene, amphibole, olivine, &c.].

Each of these divisions is first sub-divided into 'phanerites' and 'aphanites,' i.e. coarse-grained (or holocrystalline) and fine-grained or dense rocks. These words being frequently repeated in the text as main-headings are somewhat misleading, since they suggest rock-names rather than adjectival qualifications defining texture. The author complains bitterly of the confusion in rock-names, but instead of attempting to

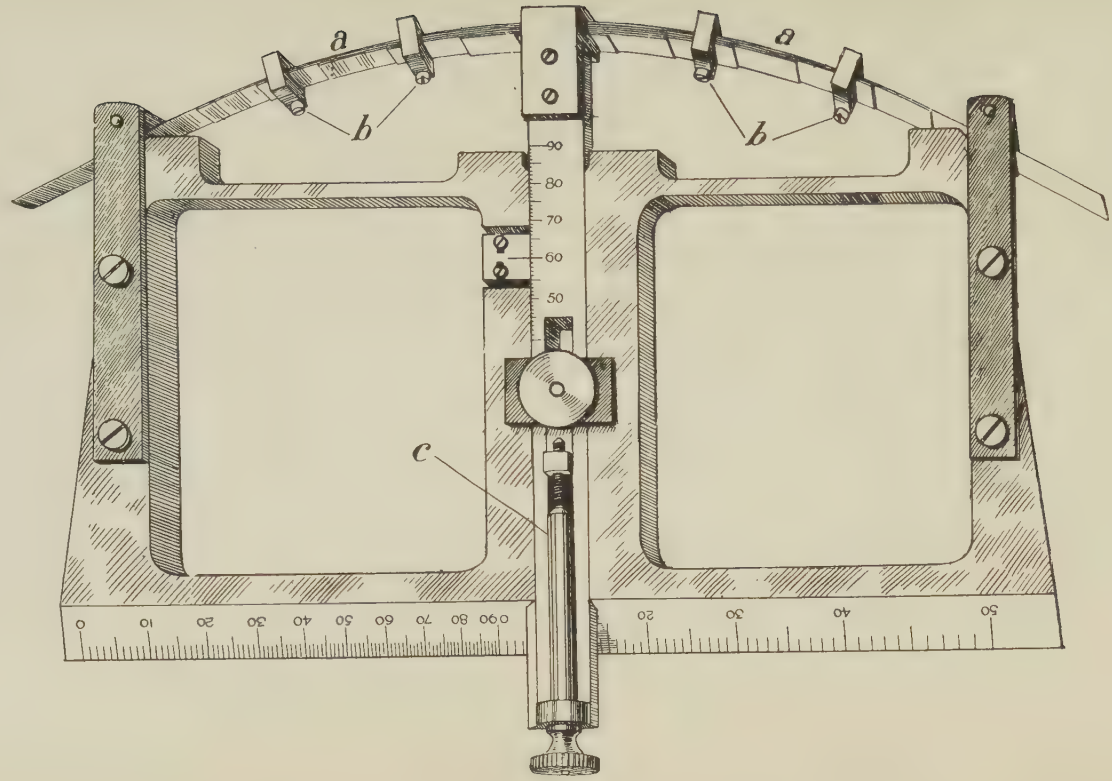
[1] This appears to be a newly-coined term, and, like 'femic' and 'femag,' it is no doubt a contraction from the words magnesium and ferrum. Like many of the uncouth words of the 'quantitative system of classification,' it bears a strange resemblance to English slang—in this case forcibly reminding us of the verb 'to maffick.' Descriptions burdened with terms of this type surely invite ridicule.

simplify he only adds to the existing confusion by introducing other less acceptable names. Fortunately, he has found it impossible to dispense altogether with the current nomenclature, which, indeed, figures largely throughout, thus rendering the volume more generally useful than it might otherwise have been.

About two thousand chemical analyses of rocks are quoted, and several diagrams representing chemical composition are given. Coloured maps of each of the continents, except Australia, show in broad outline the distribution of igneous and metamorphic rocks. The second part of the volume contains a useful, though much condensed, summary of the literature relating to the distribution of igneous rocks in each country. Even here we find evidence of the author's passion for new classifications: e.g. under the heading 'Great Britain' are included Ireland and Spitzbergen. A new, but not quite perfect, system of classification has also been devised for the numerous bibliographical references that are cited.

A Manual of Petrology. By F. P. Mennell. Pp. [v] + 256, with 123 text-figs (London: Chapman & Hall. 1913. Price 7*s.* 6*d.* net.)

This book was originally intended as a third edition of the author's 'Introduction to Petrology' (1909, second edition 1910), but so many changes have been made that it now appears under a new title. It is elementary in character, and is well printed and illustrated. The first 80 pages treat of polarized light and the rock-forming minerals. Then follow 93 pages on the igneous rocks, their classification, structure, origin, and description of the more important types; 12 pages on the sedimentary rocks; and 59 pages on the metamorphism and weathering of rocks. Finally there are short chapters on the chemistry and radioactivity of rocks, and on the collection of material and the preparation of thin-sections. A large number of the examples and figures relate to material collected by the author in Rhodesia, so that the book contains many new facts of interest to petrographers. Further, owing to the originality of his ideas, more especially with regard to the origin of igneous rocks, the author raises many points for discussion.



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